

REPRODUCTION QUALITY NOTICE

This document is the best quality available. The copy furnished to DRDCIM contained pages that may have the following quality problems:

- : Pages smaller or Larger than normal
- : Pages with background colour or light coloured printing
- : Pages with small type or poor printing; and or
- : Pages with continuous tone material or colour photographs

Due to various output media available these conditions may or may not cause poor legibility in the hardcopy output you receive.

☒ If this block is checked, the copy furnished to DRDCIM contained pages with colour printing, that when reproduced in Black and White, may change detail of the original copy.

DEFENCE



DÉFENSE

Smart Rapid Structural Analysis (SRSA) for a Bulk Carrier Hopper Structure

*D C. Heath
DREA*

*N.G. Pegg
DREA*

*T. MacAdam
Martec Ltd*

*M E. Norwood
Martec Ltd*

Defence R&D Canada

Technical Memorandum

DREA TM 2001-170

January 2002



National
Defence

Défense
nationale

Canada

Copy No: _____

Smart Rapid Structural Analysis (SRSA) for a Bulk Carrier Hopper Structure

D.C. Heath
DREA

N.G. Pegg
DREA

T. MacAdam
Martec Ltd

M.E. Norwood
Martec Ltd

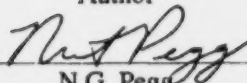
Defence Research Establishment Atlantic

Technical Memorandum

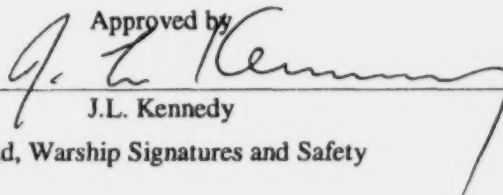
DREA TM 2001 – 170

January 2002

Author


N.G. Pegg

Approved by


J.L. Kennedy
Head, Warship Signatures and Safety

Approved for release by

K. Foster

Chairman, Document Review Panel

© Her Majesty the Queen as represented by the Minister of National Defence, 2002

© Sa majesté la reine, représentée par le ministre de la Défense nationale, 2002

Abstract

This technical memorandum describes the development of a new approach to increasing the efficiency of structural modelling and analysis and its application to commercial hopper structures of bulk carriers. This approach is entitled SRSA (Smart Rapid Structural Analysis) which makes use of DREA's object-oriented programming system, HOOD TK (Hierarchical Object Oriented Developers Tool Kit) which has been developed over the past several years to improve the development of software applications for naval ship structures. The HOOD TK is used for the development of 'Smart Object Models' (SOMs) which are programming entities that fully describe the geometry and analysis parameters of a structural component (ie. decks, bulkheads) and its relationship to other components. The SOMs are used to describe all of the basic ship structural components which are assembled, as required, into larger structural component applications through a 'Parametric Object Model' (POM). The bulk carrier hopper described in this report is a POM application. This TM describes the base Hopper POM development which has been used to produce specialized POMs for classification societies who are using it for fatigue analysis. The Hopper POM application is executed from the code DSA (Detail Stress Analysis) which extracts data from a global MAESTRO finite element model of a bulk carrier to populate the POM database and then receives the detail finite element model created from the Hopper POM application for use in fatigue analysis. The Hopper POM application has reduced finite element mesh production from several weeks to a couple of hours or less.

Résumé

Le présent document technique décrit la création d'une nouvelle méthode pour améliorer l'efficacité de la modélisation et de l'analyse structurales et de leur application aux structures des trémies des vraquiers commerciaux. Cette méthode est dénommée SRSA (Smart Rapid Structural Analysis ou analyse de structures rapides et intelligentes), qui fait appel au système de programmation orienté objet HOOD TK (Hierarchical Object Oriented Developers Tool Kit ou Trousse d'outils pour développeurs de conceptions hiérarchiques orientées objet) du CRDA. Ce système a été élaboré au cours des dernières années en vue améliorer le développement d'applications logicielles pour les structures des navires. Il sert au développement de «modèles d'éléments intelligents» (SOM), qui sont des entités de programmation donnant une description complète de la géométrie et des paramètres d'analyse des composants structuraux (p. ex. ponts et cloisons) et de leurs liens avec d'autres composants. Ces modèles servent à décrire tous les composants structuraux de base du navire qui sont assemblés, au besoin, en composants structuraux plus importants grâce un « modèle d'éléments paramétriques » (POM). La trémie de vraquier décrite dans ce rapport est une application des modèles POM. Le présent document technique décrit le développement du modèle POM de trémie qui a servi à produire des modèles POM spécialisés pour les sociétés de classification qui s'en servent pour les analyses de fatigue. L'application du POM de trémie est exécutée par le code DSA (analyse de contrainte détaillée) qui extrait des données d'un modèle global d'un vraquier à éléments finis MAESTRO pour compléter la base de données du modèle POM et reçoit ensuite le modèle détaillé à éléments finis créé par le POM de trémie pour l'utiliser dans l'analyse de fatigue. Ce POM a permis de réduire le temps de production du réseau maillé des éléments finis de plusieurs semaines à deux heures ou moins.

This page intentionally left blank.

Executive summary

Introduction

Over the past several years, DREA has been developing computer methods to improve the efficiency of structural modelling and analysis. The HOOD TK (Hierarchical Object Oriented Developers tool kit) was developed to provide a means of creating object-oriented computer code for DREA ship analysis applications. This has enabled a common framework for development and re-use of programming modules across various applications. The HOOD TK has been used to create Smart Object Models (SOMs) which are object-oriented programming entities describing ship structural components including their geometry, relationship to other components and information on how to produce effective finite element models of themselves. Complete structural models can be assembled from these SOMs through a higher level modelling application called a Parametric Object Model (POM). This overall approach to structural modelling and analysis has been termed SRSA for Smart Rapid Structural Analysis. While the SRSA developments have been aimed at Naval ships, DREA also has interests in pursuing commercial applications of its work. This TM describes the application of the SRSA technologies to commercial bulk carrier hopper structure, a project which DREA undertook collaboratively with Martec Ltd. of Halifax, Nova Scotia. The DREA/Martec computer code DSA (Detail Stress Analysis) has been used as the background finite element engine and data source within which the Hopper POM operates.

Principal Results

This project realized the first successful application of the SRSA approach in the commercial sector. The speed of producing structural models of hoppers was reduced from weeks to a couple of hours and lessened the user's requirement of knowledge of specific finite element modelling and analysis programs. The development of the code highlighted the requirement for programmers who are highly skilled in C++ object-oriented programming and naval architecture principals.

Significance of Results

The successful completion of this Hopper POM has allowed commercial structural analysis authorities to undertake comprehensive fatigue analyses of bulk carriers much more efficiently, which leads to increased safety. This base Hopper POM development provided a framework under which specialized applications were developed for classification societies on a fee for service basis. Developments for the Hopper POM are directly relevant to DREA work in Naval applications which benefited from the work described in this TM.

Future Plans

DREA continues to develop the SRSA methods through the HOOD TK, SOM and POM technologies, both for Navy and commercial applications. This work is expanding rapidly, only limited by the number of available experienced computer scientists. The approach to these developments is also attractive in developing models for the expanding modelling and simulation activities of interest to Navies worldwide.

Heath, D., Pegg, N. G., MacAdam T., Norwood M.E., (2001). Smart Rapid Structural Analysis (SRSA) for a Commercial Bulk Carrier Hopper. (TM 2001-170). Defence Research Establishment Atlantic.

Sommaire

Introduction

Depuis plusieurs années, le CRDA développe des méthodes informatiques pour améliorer l'efficacité de la modélisation et de l'analyse des structures. Le système HOOD TK (Hierarchical Object Oriented Developers tool kit – Trousse d'outils pour développeurs de conceptions hiérarchiques orientées objet) a été développé pour fournir un moyen de créer un code informatique orienté objet pour les logiciels d'analyse des structures de navires du CRDA, ce qui a permis l'établissement d'un cadre pour le développement et la réutilisation des modules de programmation sur divers logiciels. Le système HOOD TK a servi à créer des «modèles d'éléments intelligents» (SOM), qui sont des entités de programmations orientées objet décrivant les composants structuraux des navires, y compris leur géométrie, leurs liens avec d'autres composants et les données sur les méthodes de production de modèles à éléments finis efficaces de ces mêmes entités. Les modèles structuraux complets peuvent être assemblés à partir de ces modèles SOM grâce à un logiciel de modélisation à plus haut niveau appelé modèles d'éléments paramétriques (POM). Ce système général de modélisation et d'analyse structural a été appelé SRSA, pour «Smart Rapid Structural Analysis», ou analyse de structures rapide et intelligente. Bien que ce système ait été développé pour les navires, le CRDA s'intéresse également aux applications commerciales de ses travaux. Le présent document technique décrit les applications des technologies du système SRSA aux structures des trémies des vraquiers, un projet que le CRDA a entrepris en collaboration avec Martec Ltd. de Halifax, Nouvelle-Écosse. Le code informatique DSA (analyse de contrainte détaillée) de CRDA/Martec a servi de moteur d'éléments finis de base et de source de données pour le modèle POM de trémie.

Principaux résultats

Ce projet a permis la première application réussie de la méthode SRSA dans le secteur commercial. La vitesse de production des modèles structuraux de trémie a été réduite de plusieurs semaines à deux heures et a permis de diminuer les connaissances requises par l'exploitant en matière de programmes de modélisation et d'analyse par éléments finis particuliers. Le développement de ce code a fait ressortir les besoins en programmeurs très compétents en programmation orientée objet et sur les principes d'architecture navale.

Importance des résultats

La réalisation réussie de ce modèle POM de trémie a permis aux autorités en analyse de structures commerciales d'entreprendre des analyses de fatigue détaillées beaucoup plus efficaces sur les vraquiers, ce qui permet d'améliorer la sécurité. Ce modèle POM de trémie a fourni un cadre de travail qui a permis de développer d'autres applications spécialisées pour les sociétés de classification sur une base de contrats de service. Les développements pour le modèle POM de trémie sont directement reliés aux travaux du CRDA dans les applications navales, qui ont bénéficié des travaux décrits dans ce

document technique.

Plans futurs

Le CRDA continue de développer des méthodes SRSA grâce aux technologies des systèmes HOOD TK, SOM et POM, tant pour la marine que pour des usages commerciaux. Ces travaux prennent rapidement de l'expansion, qui n'est limitée que par le nombre d'informaticiens expérimentés disponibles. La technique de ces développements est aussi attrayante pour la mise au point de modèles pour les activités croissantes de modélisation et de simulations de toutes les marines du monde.

Heath, D., Pegg, N. G., MacAdam T., Norwood M.E., (2001). Analyse de structures rapide intelligente (SRSA) pour une trémie de vraquier commercial. (TM 2001-170). Centre de recherches pour la défense (Atlantique).

Table of contents

1.	Introduction.....	1
2.	Top-Down Finite Element Analysis of Ship Structure.....	4
3.	The HOOD TK Programming Environment.....	6
3.1	Smart Object Models (SOMs).....	7
3.2	Parametric Object Models (POMs).....	8
3.3	HOOD TK Finite Element Mesher.....	9
4.	The Hopper POM Application.....	10
4.1	Detailed Hopper POM Operations – DSA.....	10
4.1.1	Start DSA and Open Maestro Model and Result Files.....	10
4.1.2	Identification Of The Hopper Detail Area Of Interest.....	11
4.1.3	Initiation of the POM Application Interface.....	12
4.2	Detailed Hopper POM Operations – MDIHOODSOM.....	14
4.2.1	Changing POM Data.....	15
4.2.2	Meshing The Hopper POM Model.....	19
4.2.3	Editing the HOOD Mesh.....	21
4.3	Exporting the HOOD FE Detail Mesh back to DSA.....	25
4.4	Creating a Hopper POM Detail Model from Scratch.....	28
4.5	Hopper POM Operations in Brief.....	30
5.	Conclusions.....	32
6.	Acknowledgements.....	33
7.	References.....	34

List of figures

Figure 1: The HOOD TK VSHIP Application for Visualizing Ship Motions and Pressures	3
Figure2: A Detail FE Model Imbedded in a Global Ship Model for Top-Down Analysis	5
Figure 3: Typical HOOD TK Application Entities	7
Figure 4: The HOOD TK Mesher	9
Figure 5: Maestro Model of Bulk Carrier Loaded into DSA	11
Figure 6: Identify the Area of Interest in DSA with the Erase/Restore Menu	11
Figure 7: Start the process through the Resources - Application Interface Menu	12
Figure 8: The DSA Application Interface (left) and the Hopper POM Structural Details Menus	12
Figure 9: Identify the Double Hull Hopper Webframe with Three Control Points	13
Figure 10: Creating the HOOD POM file from DSA	14
Figure 11: HOOD POM of Hopper and the MDIHOODSOM Application	15
Figure 12: The Smart Object Models that Form the Hopper POM.....	16
Figure 13: POM Property Pages for Hopper.....	16
Figure 14: Modify HopperWeb Cutout Wizard and Scarfing Bracket Property Page	17
Figure 15: Carling Creation Wizard for Creating Carling Bracket SOM	18
Figure 16: Carling Bracket (darker blue) in POM	18
Figure 17: Tank-top SOM Property Page and Stiffener Distribution Wizard.....	19
Figure 18: The FE Mesh Automatically Created from the POM model	20
Figure 19: Structure, Boundary Detail Model and Resulting Mesh.....	21
Figure 16: Meshloops and Lines for the Hopper Boundary Detail Model.....	21
Figure 21: Initiating the Meshing Options to Change the Mesh.....	22
Figure 22: Meshing Options and Interactive Keypoint Sizing Windows	23

Figure 23: The Interactive Mesh Edge Sizing and Global Keypoint Mesh Sizing Windows...23

Figure 24: The Global Keypoint Mesh Biasing Window 24

Figure 25: Example of Interactive Keypoint Mesh Sizing with Scale of 0.6.....24

Figure 26: Interactive Mesh Edge Sizing Operation and Resulting Mesh (inset).....25

Figure 27: Exporting MDIHOODSOM FE mesh to DSA database file 26

Figure 28: The HOOD FE Mesh Imported into DSA 26

Figure 29: DSA Generated Master and Slave Nodes for Top-Down Analysis.....27

Figure 30: Shell Element Stress Plot from DSA Solver.....27

Figure 31: Beam Element Stress Plot at Stress Point Locations 28

Figure 32: Starting a POM Hopper Model from Scratch 29

Figure 33: POM Property Page and Default POM Hopper Model to Create a New Model 30

1. Introduction

Analysis of ship structures, particularly for fatigue assessment of complex structural configurations, is usually undertaken with finite element analysis (FEA). This requires considerable expertise in the particular FEA software package and considerable time in developing the models. The rapid increase in available computing power has led to significant advances in applying FEA to ship structures. The ship analysis program MAESTRO [1] has allowed more efficient production and analysis of full ship finite element models for global structural response. A complementary program developed by DREA and Martec Ltd of Halifax, Nova Scotia entitled DSA (Detail Stress Analysis) [2] allows the semi-automated extraction of global structural information to be used in producing FE models of structural details. DSA also has incorporated some specific application software for fatigue analysis, ultimate strength assessment and other analyses related to ship structures. Even with these significant advances, MAESTRO and DSA still require considerable expertise and time to produce models and undertake analysis of detail ship structure. Typically it may require 2 to 3 months to produce a global MAESTRO model of a ship and 2 to 4 weeks to produce models and undertake an analysis of a structural detail. This amount of time limits the extent to which FEA can be used for analysis.

Over the past several years, DREA has been developing computer methods to improve the efficiency of ship structural modelling and analysis. This is primarily to provide tools for naval engineers and architects who often do not have time to become expert in using specific programs, but do require the benefits of advanced analysis methods to better operate and maintain their fleet. In recognition of the proliferation of Windows based applications that are readily learned and used by almost everyone, DREA developed the HOOD TK (Hierarchical Object Oriented Developers Tool Kit) to provide a means of creating object-oriented computer code for 'Windows' ship analysis applications. The HOOD TK has enabled a common framework for software development of applications for use in various types of analysis. Figure 1 shows a typical HOOD TK application (in this case ship motions and pressure visualization).

Two of the main problems encountered when applying FEA to ship structures are; the expertise requirements of the user, and the length of time to produce models. In order to address these problems, DREA has applied the HOOD TK to create Smart Object Models (SOMs) which are object-oriented programming entities describing ship structural components including their geometry, relationship to other components and information on how to produce effective finite element models of themselves. Complete structural models can be assembled from these SOMs through a higher level modelling application called a Parametric Object Model (POM). The POM is used to very rapidly assemble a detailed

geometric model of the ship structural configuration of interest and then automatically produce suitable FE meshes of the structure for analysis. The SOM-POM approach relieves the user from requiring expertise in putting together a finite element model as it inherently contains the required information and ability to produce models of ship structure. The time to produce models is greatly reduced as, once a SOM is created for a particular type of structure, it only takes a matter of minutes to produce meshes for that structure for any location, dimensions or orientation. This overall approach to structural modelling and analysis has been termed SRSA for Smart Rapid Structural Analysis.

While the primary goal of the SRSA technology is to improve the Canadian Navy's use of finite element analysis technology to manage the CF fleet, DREA has also pursued external interest in this approach. Other Navies have expressed interest and in some cases are jointly funding specific POM developments for Naval ships and submarines. The POM-SOM approach to rapidly producing specific ship structural detail finite element models has also been presented and discussed with a number of commercial agencies, primarily classification societies and users of the MAESTRO-DSA programs. The potential to produce finite element models of commonly used details in a few hours or even minutes, as opposed to weeks, was very attractive to the class societies and both Lloyds Register of Shipping (LR) and Bureau Veritas (BV) entered into contracts with DREA and Martec Ltd to further develop base SOM classes and specialize them into bulk carrier hopper POMs for their use in finite element fatigue analysis.

This report summarizes the base Hopper POM development which is common to the work produced for both LR and BV and which is also being used in other POM developments for Naval details. Features specific to the LR or the BV Hopper POMs are proprietary and are not presented here. The DREA/Martec computer code DSA (Detail Stress Analysis) has been used as the background finite element engine and data source within which the Hopper POM application operates.

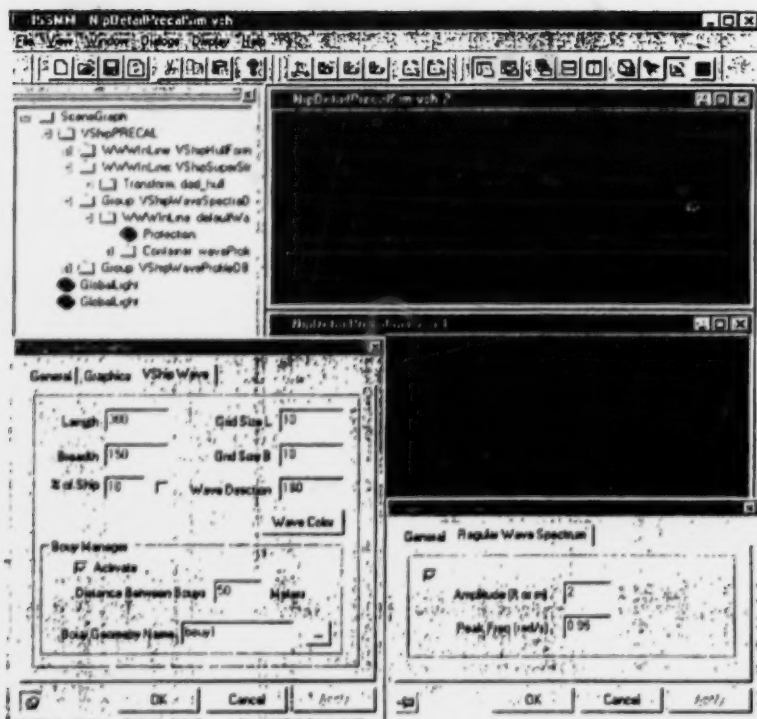


Figure 1: The HOOD TK VSHIP Application for Visualizing Ship Motions and Pressures

2. Top-Down Finite Element Analysis of Ship Structure

FEA of ship structure poses a special problem in that the entire ship, or a large portion of it, has to be modelled in order to properly apply the loads from the sea environment, while at the same time very detailed FE models are required of the local areas of interest for fatigue. It is not practical to produce a fine FE mesh of the entire ship, therefore a method called 'top-down FEA' which uses a combination of global and detail models is used. The global ship model is a coarse finite element mesh model (possibly using Maestro [1]) of either the entire ship or a longitudinal section of it. Loads are applied to the global model as pressure and inertia forces from three-dimensional sea load codes, and/or as sectional bending moments and shear forces. Separate fine mesh FE models are created for the detail areas of interest. Displacements are transferred between the coarse mesh model and the fine mesh model at the boundary of the detail model to translate the effects of the sea loads to the detail. Figure 2 shows a detail model imbedded in part of a global ship model.

DSA (Detail Stress Analysis) is a program that was created to facilitate the creation of detail FE meshes and provide the data interfaces between models for top-down analysis. The top-down interface is undertaken by automatically identifying nodes that are common to the Maestro global model (or other global FE model) and the detail DSA FE model. These common nodes become master nodes on the boundaries between the global and detail models. Other nodes, which may be created on the boundary of the detail model, are automatically slaved to the master nodes to give the correct translation of displacement boundary conditions between the two models. In addition to creating the detail meshes and handling the top-down analysis data and the FE analysis itself, the DSA code also has facilities to verify the models and plot displacement and stress results. Current DSA developments include connections to other FE packages such as ANSYS and NASTRAN, an integration of an ultimate strength analysis code and a variety of sea load codes.

The course-mesh global model is often created as part of the ship design and is available during design and through the ships life for further analyses. The local detail models are usually created on an as-needed basis, for known problem areas, for areas which show potential for problems due to high stresses or unique configurations, or for problems that arise through service. Using the top-down process, such as provided by DSA, allows the results from the global model and its design loads to be continuously used in conjunction with fine mesh models of the areas of interest. The fine mesh models need to be produced as efficiently as possible to meet time constraints (possibly to provide emergency analysis of ship damage). A rapid production of fine mesh models also allows for more variations of design to be investigated, thus allowing the analyst to explore more effective solutions. While programs such as DSA and commercial finite element modellers provide effective general purpose modellers, they still require considerable user expertise and time to produce models of ship details. The SRSA concept has been developed to address the efficiency of detail modelling and analysis.

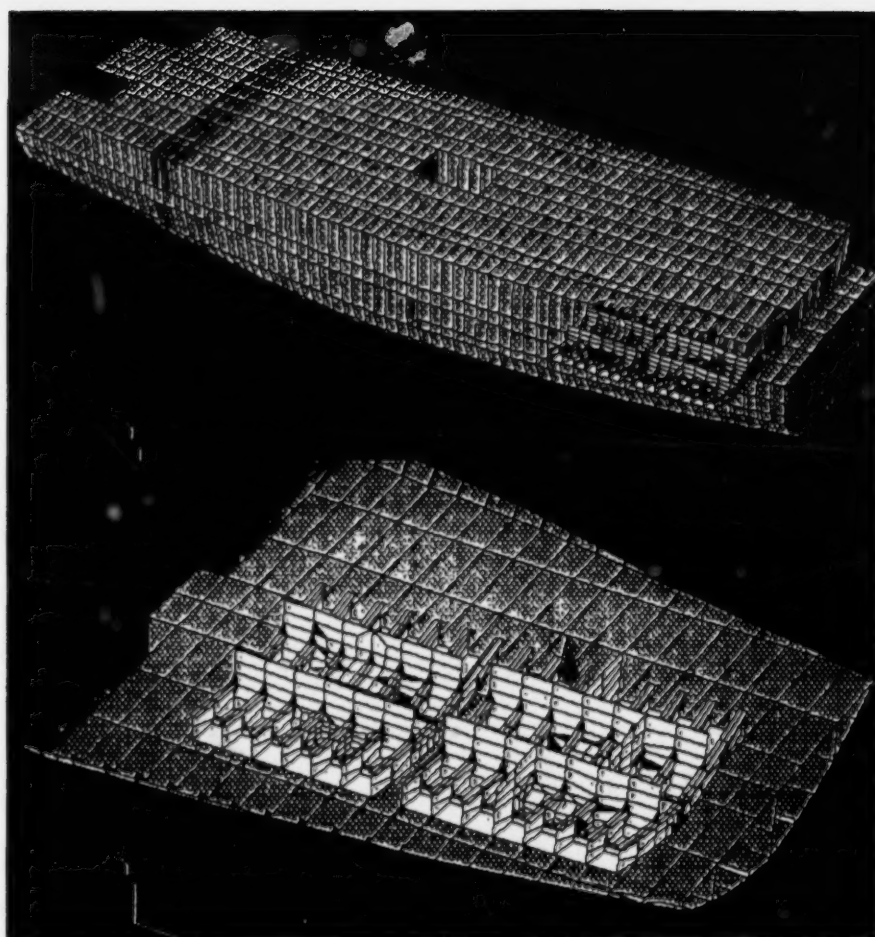


Figure2: A Detail FE Model Imbedded in a Global Ship Model for Top-Down Analysis

3. The HOOD TK Programming Environment

DREA has been involved in software development for ship structures applications for many years. Most of this involved engineering applications developed in Fortran by DREA and Canadian industry scientists and engineers. These applications were functional but fairly basic in operation, had little in the way of configuration management, and did not include the extensive user interface functions which are common to current software products. To bring its ship analysis software inline with modern programming practice, DREA began to develop a unified approach to software development to improve program continuity, maintenance and user interfaces to be consistent with commercially available software. The new approach was based on object-oriented programming (OOP) with the C++ language, and the re-use of coded objects that provided common functions across applications. The approach and the large collection of objects that have been and are being developed is titled HOOD TK for Hierarchical Object-Oriented Developers Tool Kit. The 'Hierarchical' term comes from the relational and hierarchical nature of the various classes and sub classes used in the C++ OOP environment as well as by the hierarchical nature of the ship structure being modelled.

The HOOD TK has lead to a number of applications which operate in a *similar manner* and have many object classes in common (re-use). Examples of applications developed or being developed are VShip for visualizing ship motions [3], MASTSAS for mast analysis, ULTSAS for ultimate strength assessment [4] and SubSAS for submarine structural analysis [5]. There has also been considerable interest by the commercial sector in the applications developed by the HOOD TK. A limitation to date in using the HOOD TK approach is the need to have experienced computer programmers, as opposed to engineers, develop code. This has required the 'retooling' of staff and the recognition that software production is a significant function requiring specific resources, rather than merely a by-product of engineering or scientific studies.

The basic HOOD TK program operating environment consists of 3 parts; the application, the user interface resource modules, and the associated domain modules. The application is responsible for assembling all of the resource modules and domain modules needed by the application (VShip, SubSAS, etc are applications). The resource modules consist of all graphical user interfaces (GUIs) which call various functions and graphics displays with which the user interacts in the modules. The Microsoft Foundation Class (MFC) has been used to develop the GUIs with the Open Graphics Language (OpenGL) being used for the graphics interface. The GUIs include standard pull down menu items such as File, View and Help and toolbars for undertaking common operations. The domain modules are collections of C++ objects and classes responsible for performing specific tasks including all of the necessary data and control flow. The collection of all of the C++ objects necessary in the representation of a finite element model is an example of a Finite Element domain class.

The HOOD Tool Kit has been used in the development of all aspects of the software

product application. This includes the model production, graphics operations, launching analysis codes and development of the Smart Object Models (SOMs). HOOD TK is written in Visual C++ version 6.

Figure 3 shows a typical HOOD TK application (in this case SubSAS for submarine analysis) and its various entities. The top menu shows the typical File, View, Window and Help menus as well as specialized Analysis and Wizard menus. The Open GL graphics window is shown which incorporates mouse-control model rotation, panning and zooming. The Object Browser is also shown which indicates the modelling hierarchy and allows access to the various menus to add data and control modelling options.

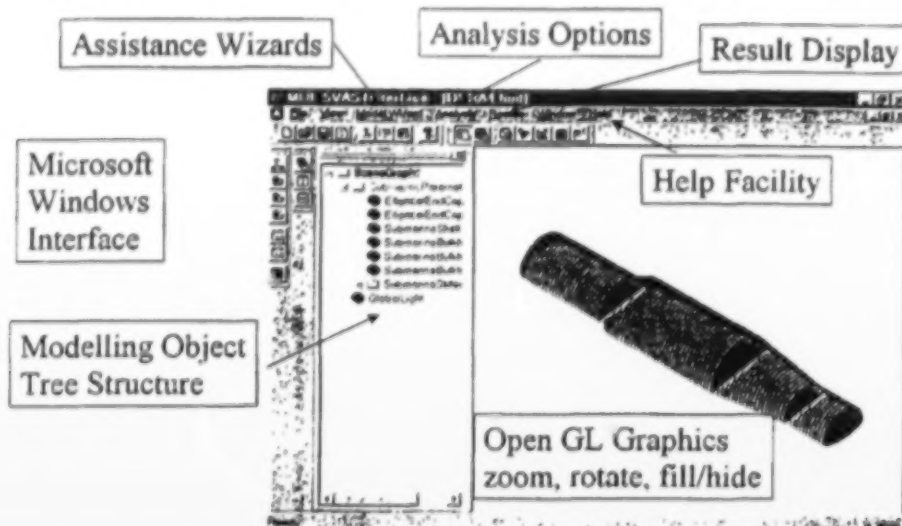


Figure 3: Typical HOOD TK Application Entities

3.1 Smart Object Models (SOMs)

In order to overcome the user requirement to be expert in applying particular finite element modelling and analysis programs and to significantly speed up the creation of finite element models, DREA developed the Smart Object Modelling (SOM) concept. The SOM entities use the HOOD TK to program 'expert systems' for finite element modelling of specific ship structure.

A SOM is a programming entity describing a structural component such as a deck or bulkhead. The SOM is a C++ programming object which embodies attributes (data) and methods that act on the attributes. The methods define relationships to other SOMs which allows SOM interactions such as automatically connecting together at the right locations (eg. deck to sideshell). The methods coded in SOMs also give the application the ability to

apply 'smart' rules for automatically producing input data for various analysis programs (such as FEA). A SOM is designed, developed and maintained so that it can be used in a number of different applications, other than the one for which it may have been originally designed. SOM information is entered through the use of GUT's such as dialogs, property sheets and wizards (shown under the HOPPER POM section below).

An important aspect of the HOOD SOM modelling approach is the relational aspect of the data objects. A hierarchy is followed such that lower order SOM objects (children) belong to higher order SOM objects (parents). This provides some of the 'smarts' in a SOM as the objects know what higher order objects they belong to and what lower order objects belong to them. This makes the organization of the data efficient and facilitates the attachment of structural objects to other structural objects. It also allows the complete geometric model to adjust itself to changes made in one or more entities. The Object Browser, shown in Figure 3, shows the hierarchical scheme and also provides direct access to the various object property data sheets.

Considering a deck stiffener as a SOM, the following would be examples of its attributes and methods:

Attributes:

- ☐ type of beam
- ☐ flange and web dimensions
- ☐ attachment point to plate if any
- ☐ beginning and end locations
- ☐ material properties
- ☐ imperfections

Methods:

- ☐ how it attaches to deck plating
- ☐ how it penetrates bulkheads
- ☐ how it attaches to other stiffeners – connections
- ☐ how to model itself as plate or beam elements

A higher order SOM such as a deck would own all of its stiffener and deck plating SOM objects.

3.2 Parametric Object Models (POMs)

A POM is a collection of SOMs that make up a specific structure that is addressed by a

HOOD TK application. The bulk carrier hopper is a POM. The POM was created as a separate programming identity as it acts as the main interface to provide data (or parameters) that describes the SOM objects. In the case of the Hopper POM, all of the POM data is either supplied initially by automatic extraction from the MAESTRO global FE model or by default values. The user may then use POM property pages to change the initial values. The user can also use the Hopper POM to build his own hopper model from scratch by entering data through the POM property pages.

3.3 HOOD TK Finite Element Mesher

In addition to the SOM and POM technologies, another key component in the SRSA approach was the development of a rapid finite element mesher. The HOOD FE mesher was developed to create meshes on complex structures described by 2D panels consisting of any number of edges (including interior edges) with any number and distribution of nodes along the edges. The mesher produces 4-node quad element grids and has controlling algorithms to prevent rapid changes in element size and to try and maintain good element shapes and aspect ratios. Figure 4 shows how the mesher works by first dividing a complex 3D structure into 2D panels defined by boundary lines. Node distributions are then defined on the boundary lines that control the mesh production. The collection of the 2D panels, lines and node distributions make up a 'boundary detail' model upon which the meshing algorithms work. The 'smart' part of the SOMs in automatically producing good FE meshes is based on default boundary detail information determined from previous parametric FE studies, and stored in the SOM database.

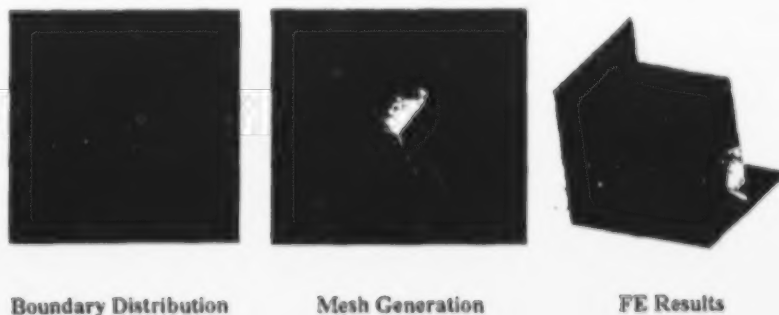


Figure 4: The HOOD TK Mesher

4. The Hopper POM Application

The Hopper POM application is presented in the form of a user's manual which goes through each step in rapidly producing FE models of a hopper detail for top-down finite element analysis. The application allows the user to identify the webframe of interest in a MAESTRO global model, launch the HOOD POM application, modify the hopper webframe parameters, create the FE mesh, edit the mesh if necessary, and bring it back into DSA and continue FE analysis operations. A section on producing a hopper model without the initial MAESTRO global model with the Hopper POM is also presented.

4.1 Detailed Hopper POM Operations – DSA

The following describes in detail the operations to begin the detail hopper model creation through DSA.

4.1.1 Start DSA and Open Maestro Model and Result Files

The process begins by starting the DSA program in MAESTRO MG mode and loading the MAESTRO finite element model (PLG file created by running MAESTRO). This provides the global geometry and the global result files from wave loads (or other load cases) which are used to define the initial data for the Hopper POM and define the input global displacements for the top-down analysis, respectively. DSA is then changed from MAESTRO (MG) mode to DSA finite element mode by using the MG>Menu button in lower right hand corner of screen.

The path of the MDIHOODSOM application on the users computer must be set upon the initial operation of the DSA-POM operation. This is done in the DSA **Resources – Configuration** submenu. DSA will store the path for future runs. Figure 5 shows a MAESTRO model of a part of the midship section of a bulk carrier loaded into DSA. The standard DSA function buttons are located along the top command row below the menu row and down the left hand column. These allow panning, zooming and rotating of the model. The user is referred to DSA manuals and help files for detailed information on using DSA [2].

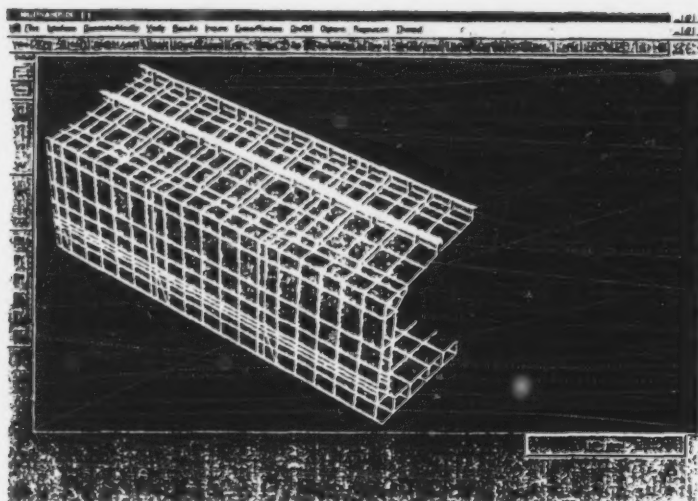


Figure 5: Maestro Model of Bulk Carrier Loaded into DSA

4.1.2 Identification Of The Hopper Detail Area Of Interest

DSA has a number of features for identifying or isolating specific structure from a global model. An **Erase/Restore** menu item allows the user to chop out parts of the model display to view only the area of interest. This aids in selecting the correct web-frame of the hopper. Figure 6 shows the hopper web frame area of interest isolated from the bulk carrier model, as well as the **Box** submenu from **Erase/Restore** used to isolate the area. Note that the **MG>Menu** button in the lower left hand corner has been toggled to **DSA>Menu**.

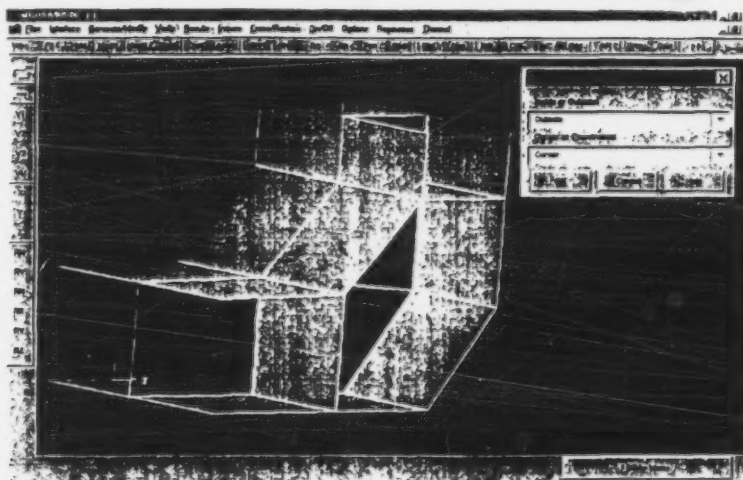


Figure 6: Identify the Area of Interest in DSA with the Erase/Restore Menu

4.1.3 Initiation of the POM Application Interface

As mentioned earlier, DSA has a number of applications related to ship structural analysis. The Hopper POM is invoked through the **Resources – Application Interfaces** menu shown in Figure 7. Figure 8 shows some of the interface GUIs and menus for the Hopper POM including the BVVS and FDA-3 application options created for BV and LR, respectively. These two applications contain proprietary analyses capabilities for the classification societies for undertaking fatigue analysis. The Hopper POM detail FE production is done through the **Structural Details** menu invoked through the BVVS or FDA-3 applications.

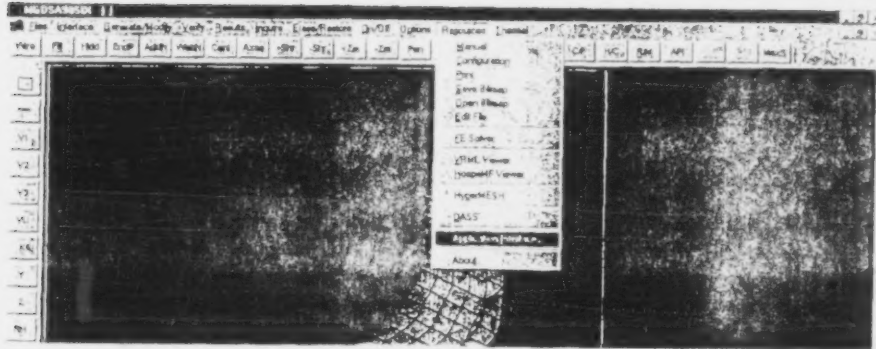


Figure 7: Start the process through the Resources - Application Interface Menu

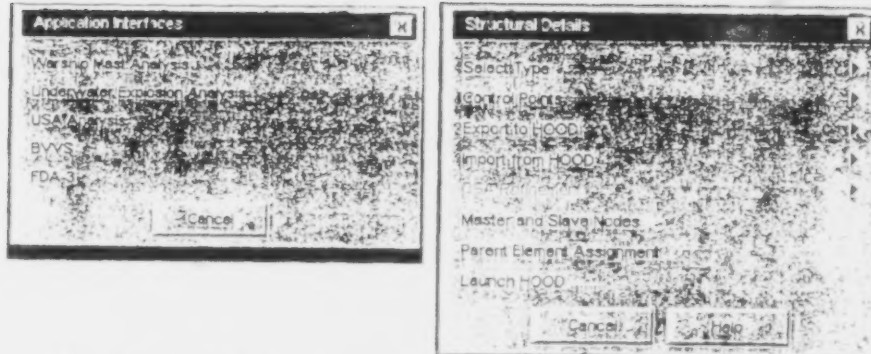


Figure 8: The DSA Application Interface (left) and the Hopper POM Structural Details Menus

The **Structural Details** menu of Figure 8 defines the process to follow in DSA to define the necessary data and initiate the Hopper POM application. The first four items invoke sub menus and the last three undertake functions directly. The first step is to select the type of hopper via the **Select Type**. The type variations are proprietary to the users and only the base hopper class is used here.

4.1.3 Initiation of the POM Application Interface

As mentioned earlier, DSA has a number of applications related to ship structural analysis. The Hopper POM is invoked through the **Resources – Application Interfaces** menu shown in Figure 7. Figure 8 shows some of the interface GUIs and menus for the Hopper POM including the **BVVS** and **FDA-3** application options created for BV and LR, respectively. These two applications contain proprietary analyses capabilities for the classification societies for undertaking fatigue analysis. The Hopper POM detail FE production is done through the **Structural Details** menu invoked through the **BVVS** or **FDA-3** applications.

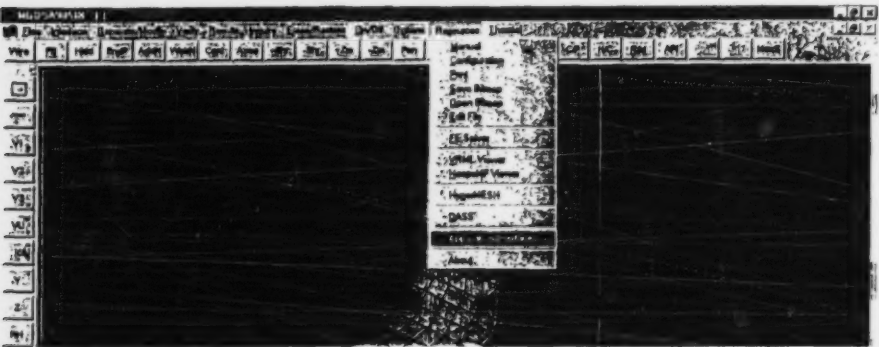


Figure 7: Start the process through the Resources - Application Interface Menu

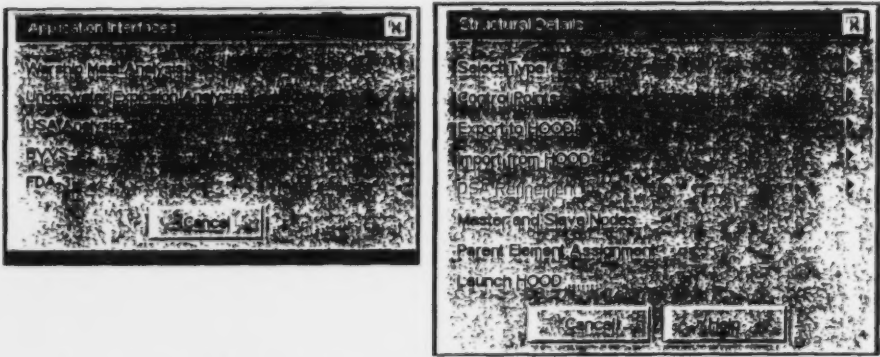


Figure 8: The DSA Application Interface (left) and the Hopper POM Structural Details Menus

The **Structural Details** menu of Figure 8 defines the process to follow in DSA to define the necessary data and initiate the Hopper POM application. The first four items invoke sub menus and the last three undertake functions directly. The first step is to select the type of hopper via the **Select Type**. The type variations are proprietary to the users and only the base hopper class is used here.

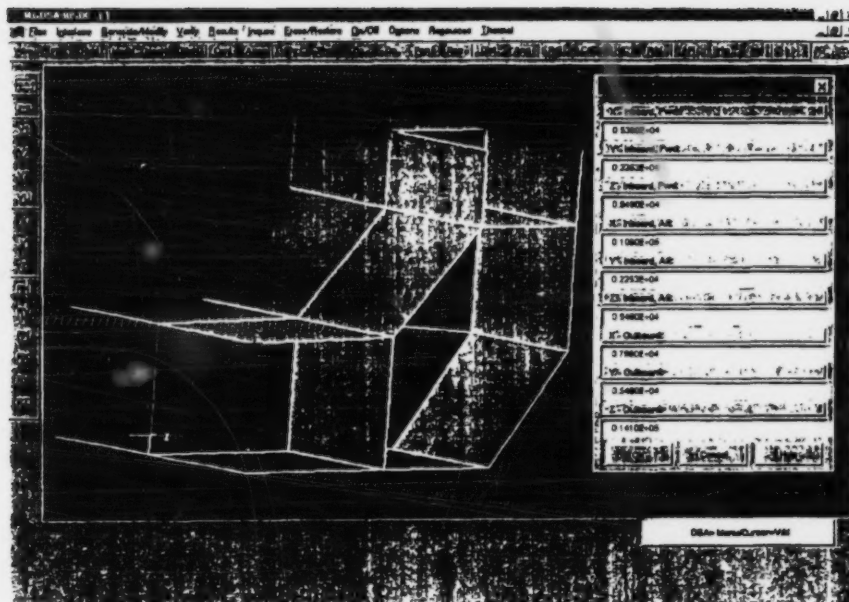


Figure 9: Identify the Double Hull Hopper Webframe with Three Control Points

The next step is to identify the specific web frame and orientation from the MAESTRO model. This is accomplished by invoking the **Control Points** menu and identifying three control points that define the hopper detail boundary, as indicated in Figure 9. The coordinate data is automatically entered in the **Control Points** data boxes by clicking on the structural intersections (nodes) on the hopper graphic. The coordinates may also be entered directly in the data boxes. The first control point is on the forward inside shell which delineates the forward and inward boundaries. The second is on the aft inside shell which delineates the aft boundary. The third is on the upper inside shell which delineates the upper boundary.

The user then presses the **Export to HOOD** menu which creates the HOOD POM geometric data file. This menu allows the creation of bilge radius data if necessary, as the MAESTRO model typically does not accurately model the bilge radius. DSA displays the Smart Object Models by different colours (Figure 10). The user then launches the HOOD Hopper POM **MDIHOODSOM** application from the **Launch HOOD** menu item. DSA extracts as much information as possible from the MAESTRO data to populate the HOOD POM file. Modifying this data to add missing information or change existing data is undertaken in the **MDIHOODSOM** Hopper POM application.

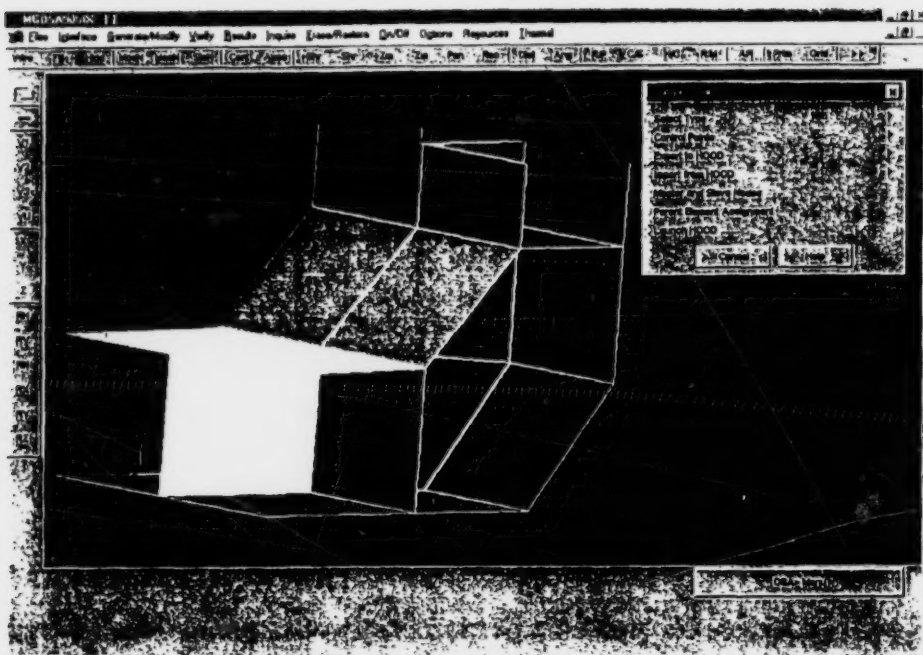


Figure 10: Creating the HOOD POM file from DSA

4.2 Detailed Hopper POM Operations – MDIHOODSOM

The HOOD Hopper POM application (**MDIHOODSOM**) is launched from DSA through the **Launch HOOD** menu. The initial view is of the POM file (Figure 11). The screen is divided up into a graphics window, a top menu bar, a second submenu item bar, a left hand graphics orientation menu and an Object Browser tree to assist in identifying and populating objects in the graphic. The basic operations in the top menu bar are:

File which allows one to load other files, this is not necessary if launched from DSA;

View which allows you to switch from the POM model to the FEM model;

POM Model which allows creation or editing of the POM data;

FEM which allows creation of the FE model and the DSA database from the POM;

Window which allows multiple HOOD files to be viewed;

Tools which allows Mesh alteration; and

Help which provides interactive user help.

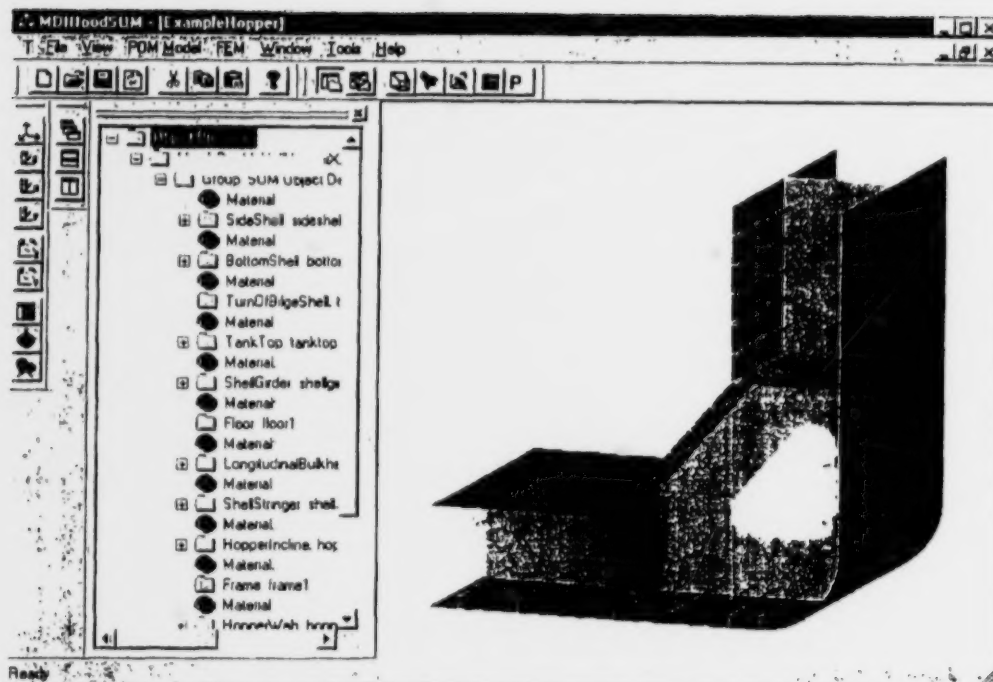


Figure 11: HOOD POM of Hopper and the MDIHOODSOM Application

4.2.1 Changing POM Data

As described above, the POM consists of Smart Object Models (SOMs) which describe the geometric entities of the hopper (for example stiffeners and tank tops). The individual SOMs are shown in Figure 12; transverse bulkhead, shell, longitudinal bulkheads, transverse outboard, hopper deck and stiffeners. The POM contains all information about scantlings, materials, initial meshing data and how its constituent SOMs are related to each other. In the Hopper Application, the POM file is populated by DSA from the MAESTRO model data. While the global model MAESTRO data is adequate for global response it may not be complete or accurate enough for the detail level (for example stiffener size and position or plate thicknesses may be averaged in the MAESTRO model) and therefore the user may wish to change or add to the information created in the POM by DSA. This is done through POM property pages as shown in Figure 13 which are invoked from the **POM Model** menu with the **ViewPOM Interface** submenu item.

A different POM file, if it already exists can be launched using the File menu. The user can also create his own model from scratch by populating the POM property pages directly.

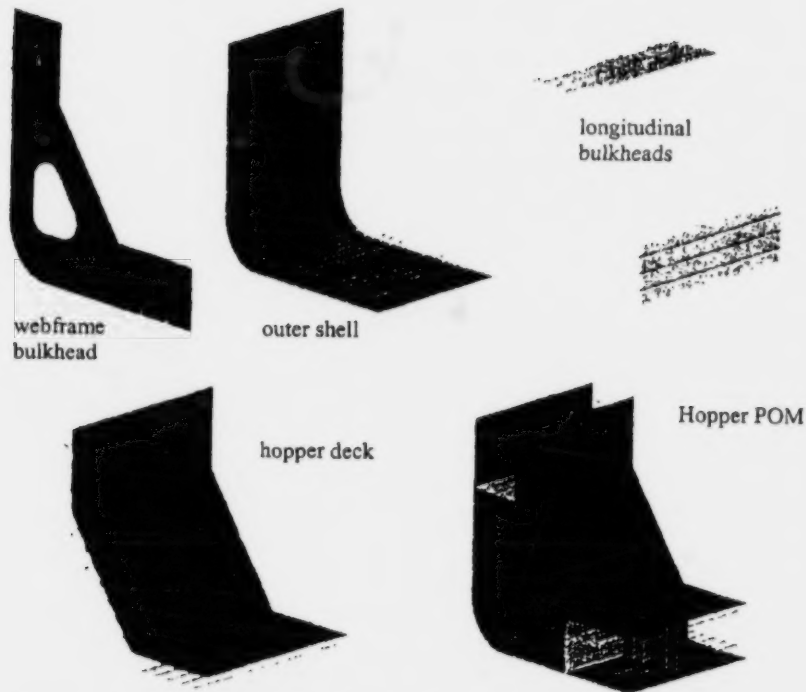


Figure 12: The Smart Object Models that Form the Hopper POM

Object Info | Object Geometry Info | Double Hull Hopper | POM Hopper

Object Info | Object Geometry Info | Double Hull Hopper | POM Hopper

☐ Include welding bracket
☐ Transverse welding bracket at web outlet
☐ Web Intersection Edge Only
☐ Modify existing bracket parameters

☐ Include web penetration
☐ Modify web penetration parameters

Corrugation
 Corrugation material:

Fatigue area of interest
☒ Lower knuckle
☐ Upper knuckle

Number of longitudinal elements on one side of symmetrical fatigue patch: (must be even)
 Number of transverse elements on one side of symmetrical fatigue patch: (must be even)

Upper knuckle: ☐ Welded ☐ Patch only
 Lower knuckle: ☐ Welded ☐ Patch only

D1: D2: D3:
 B1: B2: B3:
 B4: B5: B6:
 L1: S:
 R:

Upper knuckle overhang thickness: ☐ Model plotted
 Lower knuckle overhang thickness: ☐ Model plotted

Figure 13: POM Property Pages for Hopper

The **Double Hull Hopper** property page on the left allows the overall dimensions of the hopper to be created or modified. It is invoked through the **View POM Interface** submenu on the **POM Model** menu. Care has to be taken in this application, as the geometry of the finished detail mesh has to coincide with the MAESTRO model from which it originated, for the top down analysis (ie. changing the deck height in the HOOD application may cause a mismatch to the deck location in the original MAESTRO file). The geometry parameters are typical of those from Class Society structural documentation. The **POM Hopper** property page on the right allows the user to create and modify brackets and web penetrations. The **Object Info** tab invokes a general class property page for naming the HOOD object and the **Object Geometry Info** tab allows general definition of the object geometry for graphics purposes such as separating the SOMs as in Figure 12.

Figure 14 shows the **HopperWeb Cutout** SOM creation wizard and the **Scarfig Bracket** SOM property page. Wizards are used to help the user enter data for SOMs. Again, the parameters are consistent with Class Society documentation. Both of these pages are invoked from the **POM Hopper** property page. Note that a coaming can be included on the cutout. The **SOMNodeX** tab gives SOM relational data to other SOMs.

Modify HopperWeb Cutout

Diagram: A cutout shape with dimensions D1, D2, D3, R1, R2, R3, and F1.

☒ Model coaming

☐ Model coaming plated

Coaming width: 200

Coaming thickness: 0

OK Cancel

NonSymmetricStraightScarfigBracket Properties

Object Info | Object Geometry Info | SOMNodeX | Scarfig Bracket

Diagram: A bracket shape with dimensions D1, D2, D3, D4, D5, H1, H2, H3, H4, R1, R2, R3, R4, and L.

D1	115 333	H3	115 333
D2		H4	96 5
D3	144 167	R1	96 5
D4	288 333	R2	96 5
D5	115 333	R3	96 5
H1	96 5	R4	96 5
H2	314 545	L	1000

OK Cancel Apply

Figure 14: Modify HopperWeb Cutout Wizard and Scarfig Bracket Property Page

Carlings bracket SOM data are inserted through the **Carling Creation Wizard** from the **POM Hopper** property page. Figure 15 shows the Carling Wizard and Figure 16 shows the completed Carling in the POM.

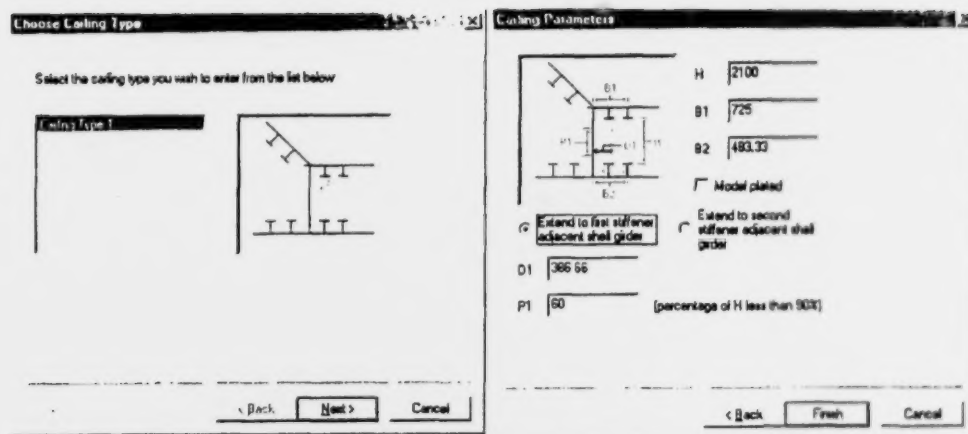


Figure 15: Carling Creation Wizard for Creating Carling Bracket SOM

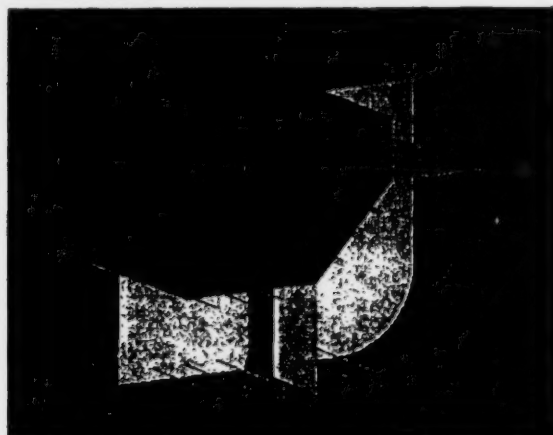


Figure 16: Carling Bracket (darker blue) in POM

Property pages exist for all SOMs. They are invoked by double-clicking on the object in the view-plane, through the object tree structure on the left side of the application or through creation wizards from other property pages. In Figure 17, the **Tank Top** SOM property page is shown which allows editing of its stiffeners and plate thicknesses. The **Stiffener Distribution** wizard, invoked from the **TankTop** property page, is also shown.

It allows definitions of the location (from the reference arrow on picture), type, material, and meshing options for stiffeners.

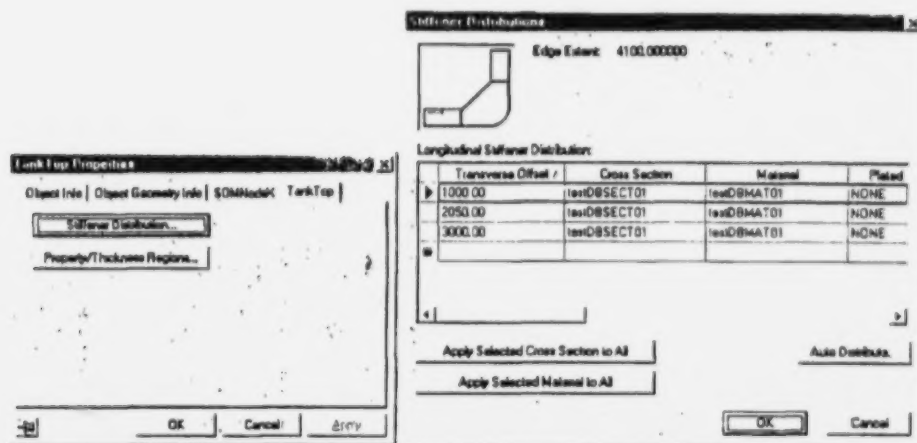


Figure 17: Tank-top SOM Property Page and Stiffener Distribution Wizard

4.2.2 Meshing The Hopper POM Model

Once the user has made all of the desired additions and modifications to the Hopper POM geometric data, the FE mesh can be created. This is done using the **FEM** menu in the Hopper POM application and the **Create FE Detail** submenu. An FE mesh is automatically created using predefined meshing parameters in the SOM data as shown in Figure 18. Note that the solid coloured stiffeners indicate that beam elements are used. For good results in attaining a mesh where the stiffeners intersect the web frame, it is best to either model the stiffener with beam elements or the flange as a beam element with the web as plate elements. While the user can model both the web and flange with plate elements, this increases the nodal and element density at the intersection with the web frame considerably, and this option should only be used where the effects of modelling the behaviour of the complete stiffener cross-section is expected to influence the stress results of interest.

The mesh in Figure 18 shows very high element density at the knuckle connection. This is the area of prime interest for fatigue calculations. Special meshing patches and parameters are used in this region to produce the element distribution required for a fatigue analysis. The exact distribution of elements depends on the users requirements for meshing hot spot regions for fatigue calculations and these meshing rules are built into the SOM object data that make up the hot spot region.

The mesh that is automatically created from the POM data, is done so with best estimates of meshing parameters. The user can edit this mesh if he wishes. In future the user will

also be able to set his own 'default' values of meshing parameters which will automatically be invoked whenever he uses the application. The basics of how a HOOD mesh is created are explained in the following.

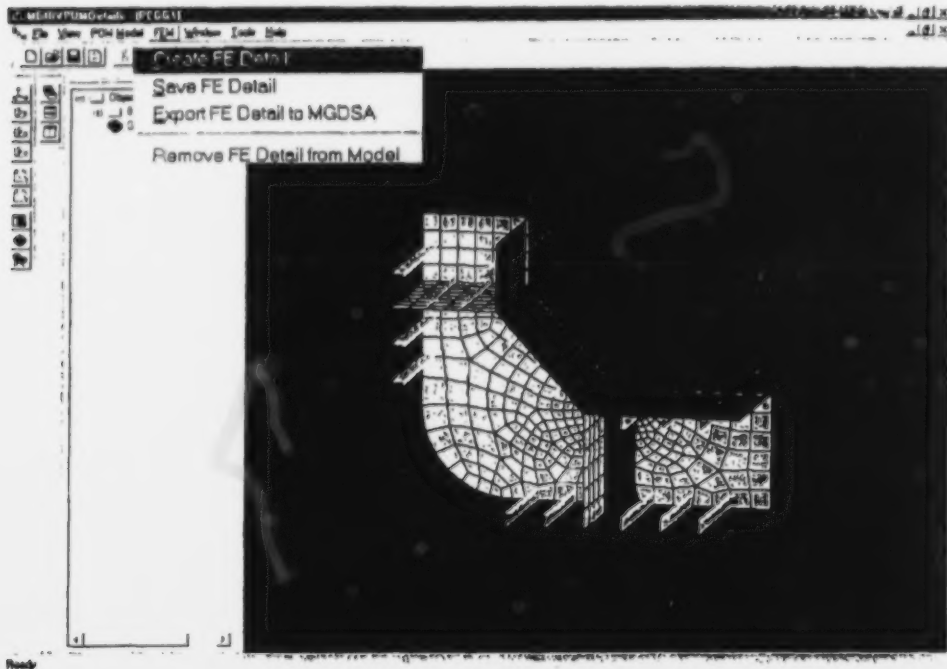


Figure 18: The FE Mesh Automatically Created from the POM model

HOOD meshing is based on dividing the structure into meshing entities or meshloops. Meshloops are 2D polygons or 3D surfaces consisting of lines. The lines are joined at keypoints. The lines have a node or point distribution. A mesher (paving algorithm) is then used to produce a mesh of quadrilateral shells in each meshloop. Continuity is maintained in the entire mesh through the common lines between meshloops. The group of meshloops, lines and keypoints which make up a complete detail model (such as the hopper) is called the boundary detail model. For the Hopper Application, all data for the meshloops, lines and keypoints are created and stored in the POM and are activated with the **Create FE Detail** submenu item to automatically produce the mesh. Figure 19 demonstrates the HOOD meshing process for a stiffener intersection which is made up of a number of meshloops, lines and keypoints. The meshloops and lines are displayed for the hopper in Figure 20. The meshloops being all of the rectangular areas bordered by lines.

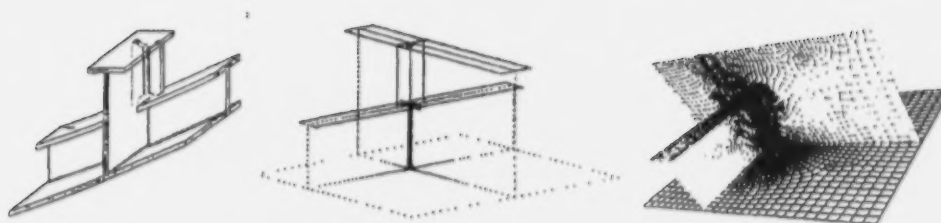


Figure 19: Structure, Boundary Detail Model and Resulting Mesh



Figure 16: Meshloops and Lines for the Hopper Boundary Detail Model

4.2.3 Editing the HOOD Mesh

The mesh creation is controlled by the node distributions along the lines. The finer the node distribution, the finer the mesh that is created in the adjoining region. The node distribution on the lines can be controlled by values assigned to the keypoints (points at line intersections). The keypoint values describe the element size directly adjacent to the keypoint on all lines that connect to that keypoint. The node distribution can also be changed directly on the line itself. Later versions of the HOOD mesher will allow creation of new keypoints, lines and meshloops, but at present, these are fixed for the Hopper Model. The following explains how to change the mesh, with the exception of the local area of fatigue interest at the knuckle. This region has a fixed mesh of size $8t \times 4t$ where t is the plate thickness. The constant mesh size is necessary to meet fatigue analysis requirements and therefore the keypoints and line distributions in this area cannot be

changed as can be done for other meshloops. Facilities to change the fatigue area meshing may be developed in the future.

To edit the mesh, the user initiates the **Meshing Options** item from the Tools menu as shown in Figure 21. The **Meshing Options** window appears (Figure 22) which allows four methods of interactively changing the mesh. *Interactive Key Point Mesh Sizing* allows the user to move his mouse to the keypoints and change them individually by a scale factor. Note that the number of keypoints, meshloops, nodes and elements is displayed in the meshing options window. These are interactively updated as the mesh is modified. Instructions on how to use the keypoint sizing are given on the invoked **Interactive Keypoint Sizing** window, also shown in Figure 22. The *Touch Sensitive Mouse* option highlights the keypoints as the mouse passes over them. The scale factor is manually entered in the data entry cell. A value less than one reduces the local mesh size and a value larger than one increases it.

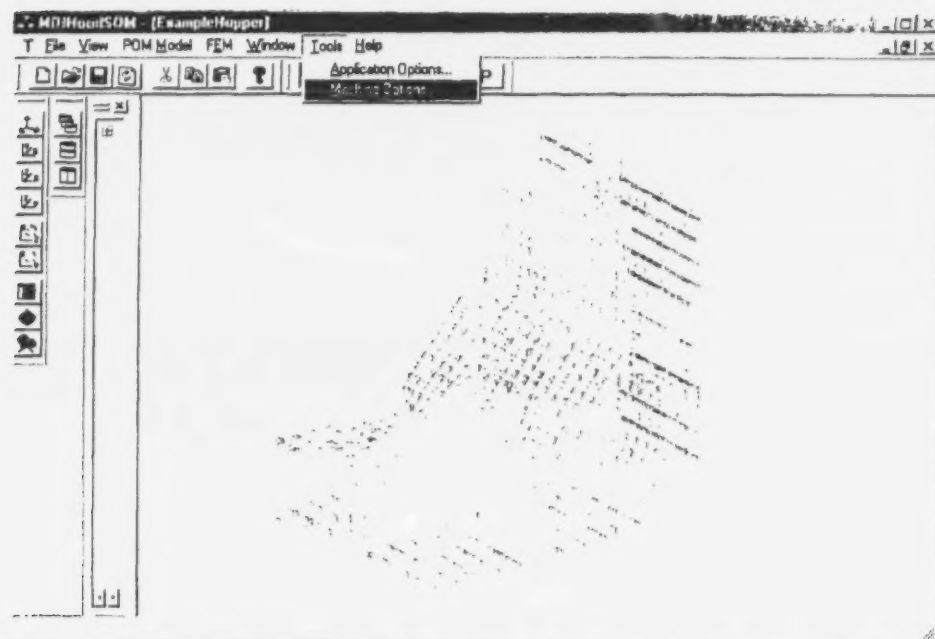


Figure 21: Initiating the Meshing Options to Change the Mesh

Interactive Edge Mesh Sizing (Figure 23) allows a similar operation on the meshloop edges. Again, the user highlights the desired edge, clicks twice with the Ctrl button held down and the node spacing on that line is adjusted and the mesh automatically regenerated. *Global Key Point Mesh Sizing* allows the scale factor to be applied to all of the keypoints in the mesh and the *Global Key Point Mesh Biasing* (Figure 24) assigns two scale factors. The lower value works on the smallest keypoint, the larger value works on the largest keypoint and the keypoints in between are scaled linearly between the two.

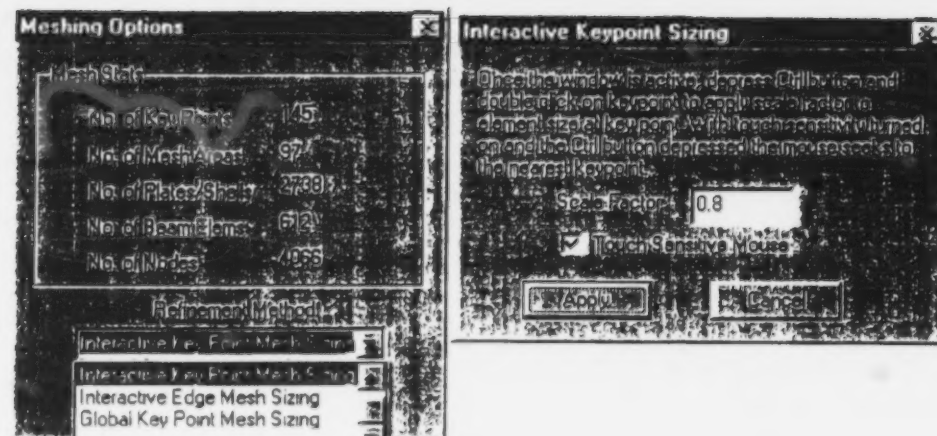


Figure 22: Meshing Options and Interactive Keypoint Sizing Windows

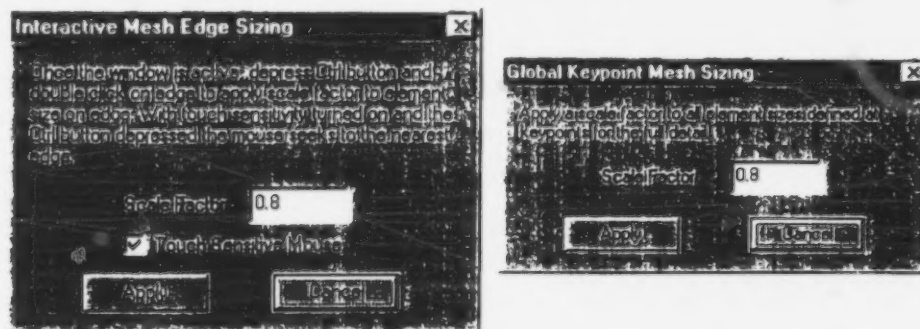


Figure 23: The Interactive Mesh Edge Sizing and Global Keypoint Mesh Sizing Windows

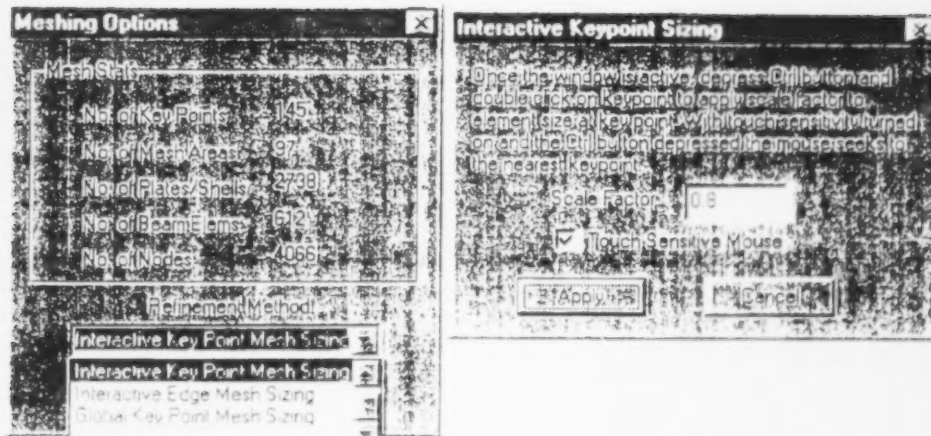


Figure 22: Meshing Options and Interactive Keypoint Sizing Windows

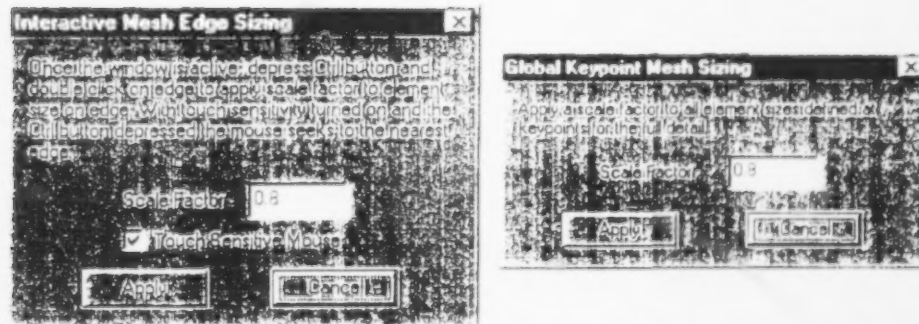


Figure 23: The Interactive Mesh Edge Sizing and Global Keypoint Mesh Sizing Windows

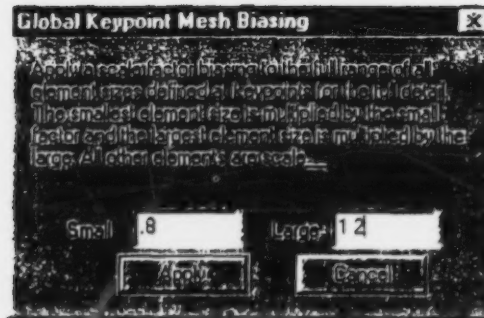


Figure 24: The Global Keypoint Mesh Biasing Window

Figure 25 shows a *Keypoint Size* change operation and the resulting mesh (inset figure) which is immediately produced on the screen as the operation is undertaken. The keypoint is highlighted with two left mouse clicks (yellow circle). Two additional left mouse clicks with the Ctrl key held down changes the keypoint size by 0.6 and reduces the associated mesh accordingly.

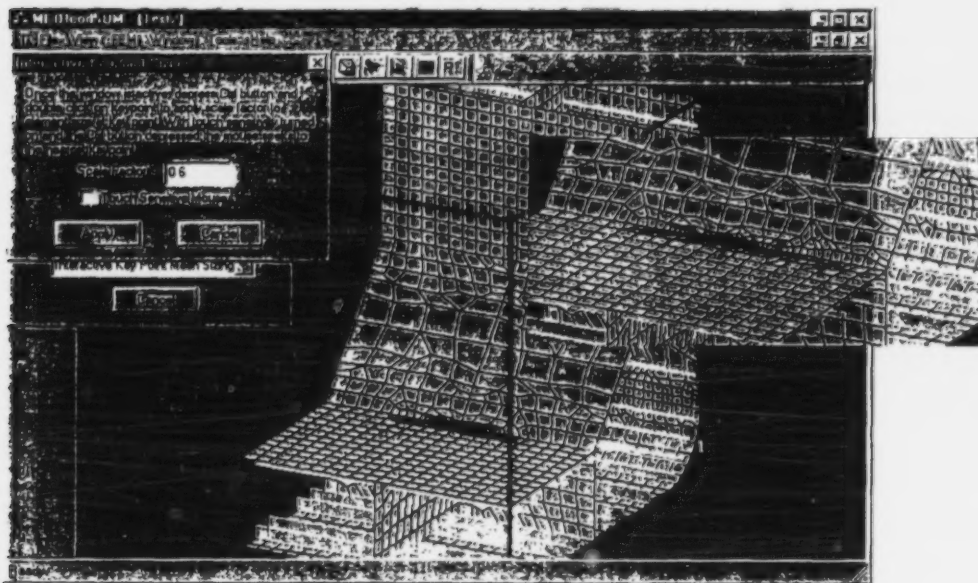


Figure 25: Example of Interactive Keypoint Mesh Sizing with Scale of 0.6

Figure 26 shows the *Interactive Mesh Edge Sizing* operation and the resulting mesh. Again the edge is highlighted by two 'ordinary' left mouse clicks (with resulting blue highlight) and the actual resizing operation is undertaken by two left clicks with the Ctrl key held down.

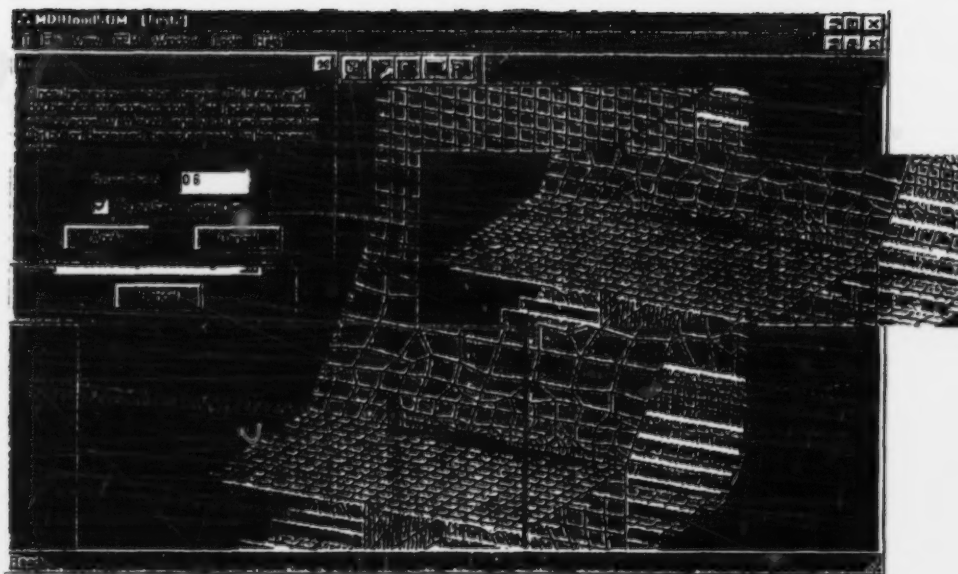


Figure 26: Interactive Mesh Edge Sizing Operation and Resulting Mesh (inset)

4.3 Exporting the HOOD FE Detail Mesh back to DSA

Once a satisfactory mesh is created it is sent back to DSA for finite element analysis using **Export FE Detail to MGDSA** from the **FEM** menu to create the DSA file (Figure 27). Normally the time spent in the HOOD Hopper POM to create the mesh is only a few minutes. The HOOD model is imported back into DSA as a detail FE model (Figure 28) using the **Import from HOOD** option in the **DSA Resources – Application Interfaces – Fatigue Analysis** menu.

Master and slave nodes are automatically generated using the **Master and Slave Nodes** menu item (Figure 29). Currently, master and slave nodes in the turn of bilge region are not automatically generated and must be generated manually through the **Generate/Modify** menu item in DSA.

The **Parent Element Assignment** menu item automatically maps the HOOD generated FE mesh elements to their corresponding MAESTRO elements by geometric coordinates. This is used for maintaining correct element loading continuity between the global and detail FE models (for example, pressure load on the outer shell in MAESTRO needs to be translated to the outer shell of the HOOD detail model).

The fatigue analysis then continues using procedures provided in the DSA Applications Interface (these are proprietary to Class societies) to produce detail stress information. Figures 30 and 31 show stress plots from the DSA solver.

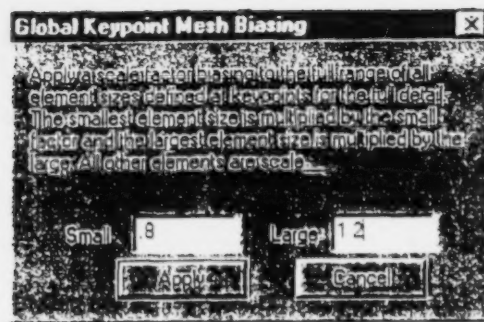


Figure 24: The Global Keypoint Mesh Biasing Window

Figure 25 shows a *Keypoint Size* change operation and the resulting mesh (inset figure) which is immediately produced on the screen as the operation is undertaken. The keypoint is highlighted with two left mouse clicks (yellow circle). Two additional left mouse clicks with the Ctrl key held down changes the keypoint size by 0.6 and reduces the associated mesh accordingly.

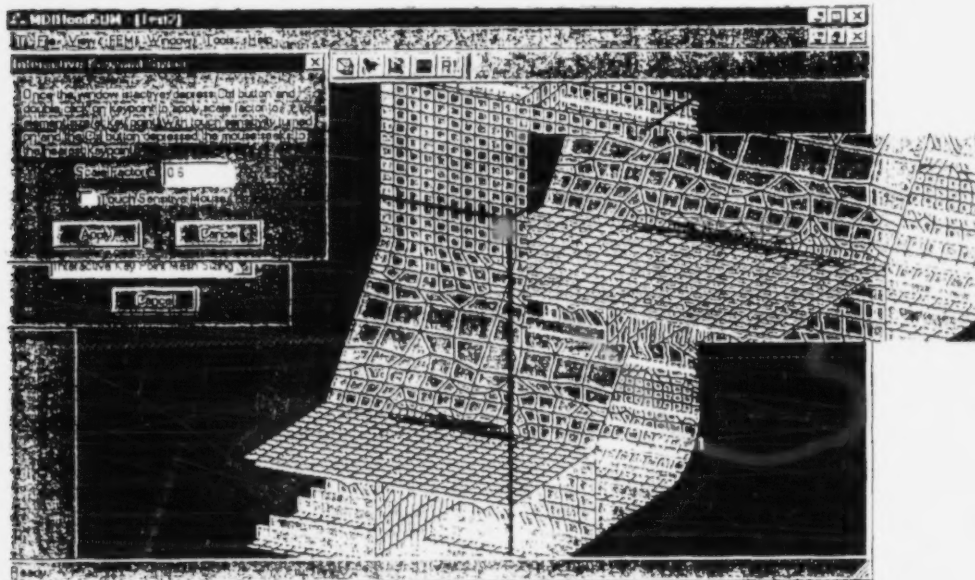


Figure 25: Example of Interactive Keypoint Mesh Sizing with Scale of 0.6

Figure 26 shows the *Interactive Mesh Edge Sizing* operation and the resulting mesh. Again the edge is highlighted by two 'ordinary' left mouse clicks (with resulting blue highlight) and the actual resizing operation is undertaken by two left clicks with the Ctrl key held down.

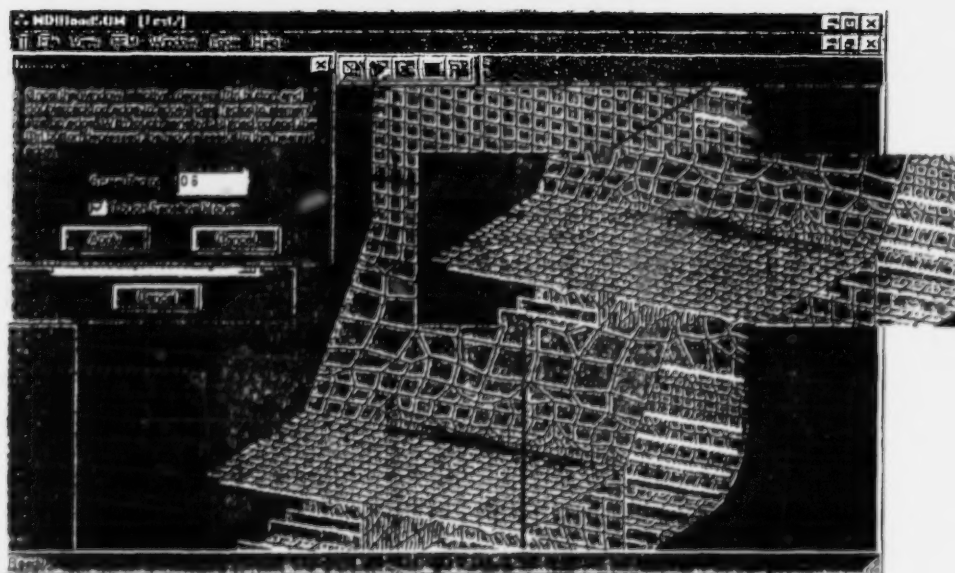


Figure 26: Interactive Mesh Edge Sizing Operation and Resulting Mesh (inset)

4.3 Exporting the HOOD FE Detail Mesh back to DSA

Once a satisfactory mesh is created it is sent back to DSA for finite element analysis using **Export FE Detail to MGDSA** from the **FEM** menu to create the DSA file (Figure 27). Normally the time spent in the HOOD Hopper POM to create the mesh is only a few minutes. The HOOD model is imported back into DSA as a detail FE model (Figure 28) using the **Import from HOOD** option in the **DSA Resources - Application Interfaces - Fatigue Analysis** menu.

Master and slave nodes are automatically generated using the **Master and Slave Nodes** menu item (Figure 29). Currently, master and slave nodes in the turn of bilge region are not automatically generated and must be generated manually through the **Generate/Modify** menu item in DSA.

The **Parent Element Assignment** menu item automatically maps the HOOD generated FE mesh elements to their corresponding MAESTRO elements by geometric coordinates. This is used for maintaining correct element loading continuity between the global and detail FE models (for example, pressure load on the outer shell in MAESTRO needs to be translated to the outer shell of the HOOD detail model).

The fatigue analysis then continues using procedures provided in the DSA Applications Interface (these are proprietary to Class societies) to produce detail stress information. Figures 30 and 31 show stress plots from the DSA solver.

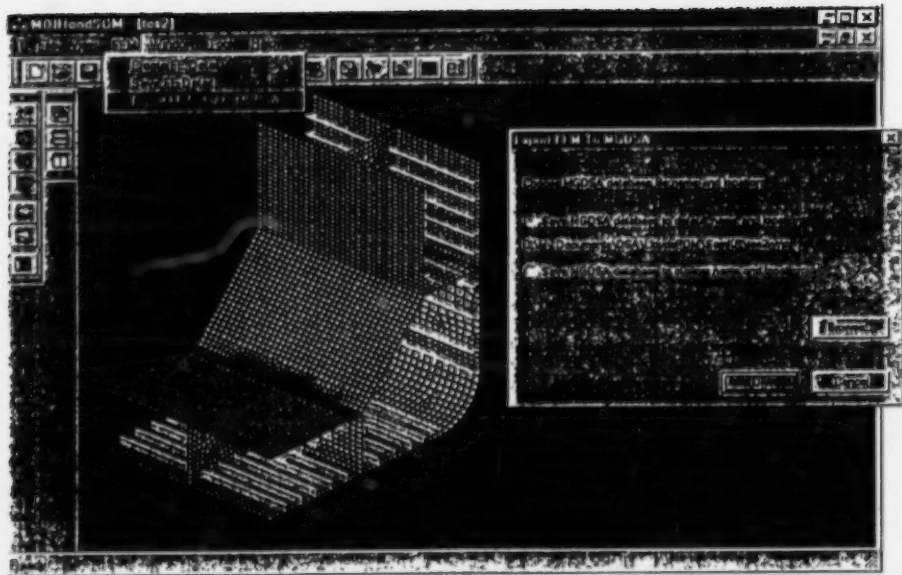


Figure 27: Exporting MDIHOOVSOM FE mesh to DSA database file

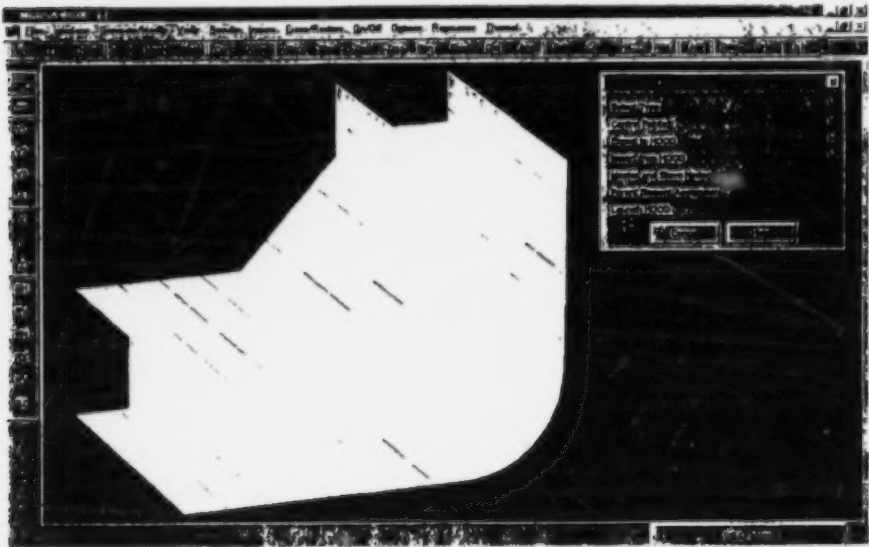


Figure 28: The HOOD FE Mesh Imported into DSA



Figure 29: DSA Generated Master and Slave Nodes for Top-Down Analysis

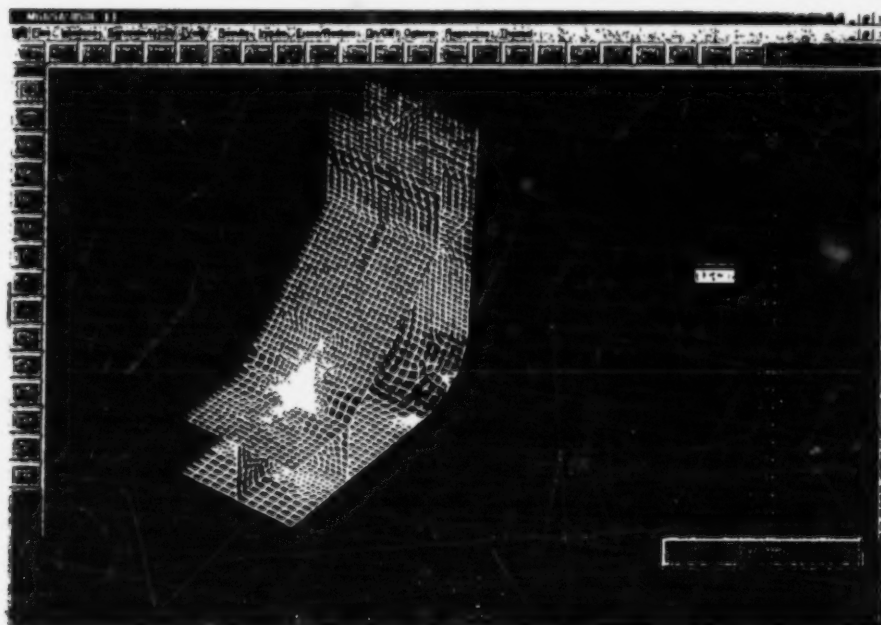


Figure 30: Shell Element Stress Plot from DSA Solver

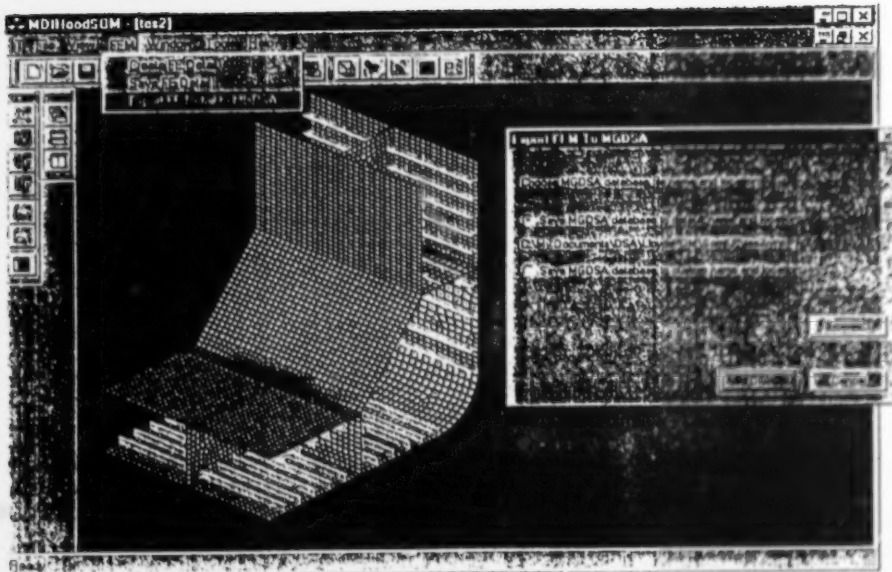


Figure 27: Exporting MDIHOODSOM FE mesh to DSA database file

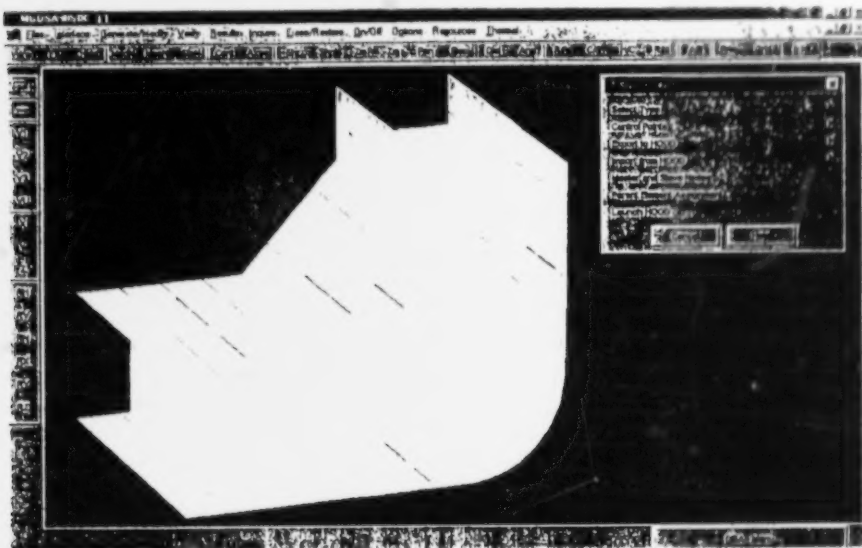


Figure 28: The HOOD FE Mesh Imported into DSA



Figure 29: DSA Generated Master and Slave Nodes for Top-Down Analysis

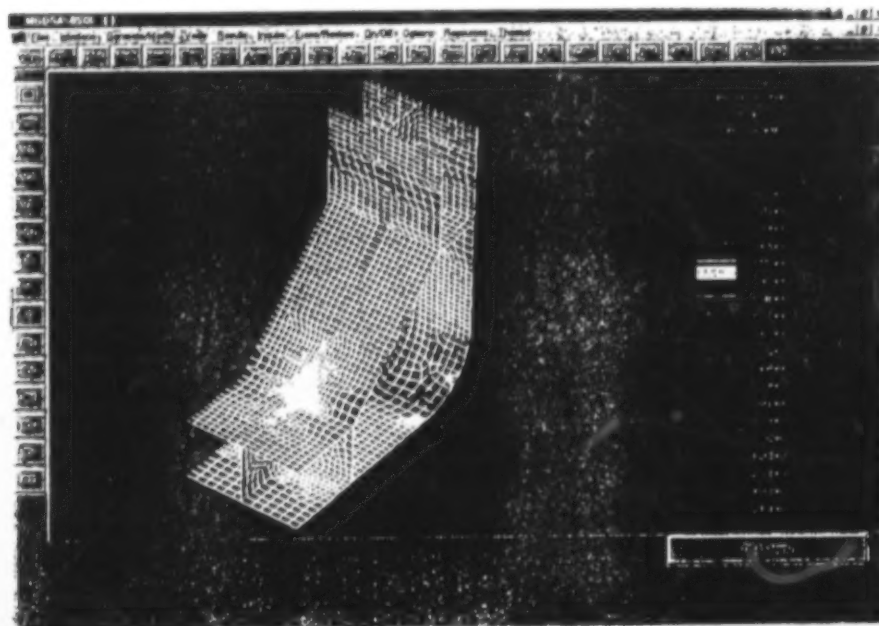


Figure 30: Shell Element Stress Plot from DSA Solver



Figure 31: Beam Element Stress Plot at Stress Point Locations

4.4 Creating a Hopper POM Detail Model from Scratch

If desired, the user can create a Hopper Detail Model from scratch, ie. not starting from a MAESTRO model and DSA. This is done entirely in the HOOD Hopper POM application. The user initiates the HOOD Hopper POM application and begins with **new** in the **File** menu. An empty view screen appears (Figure 32).

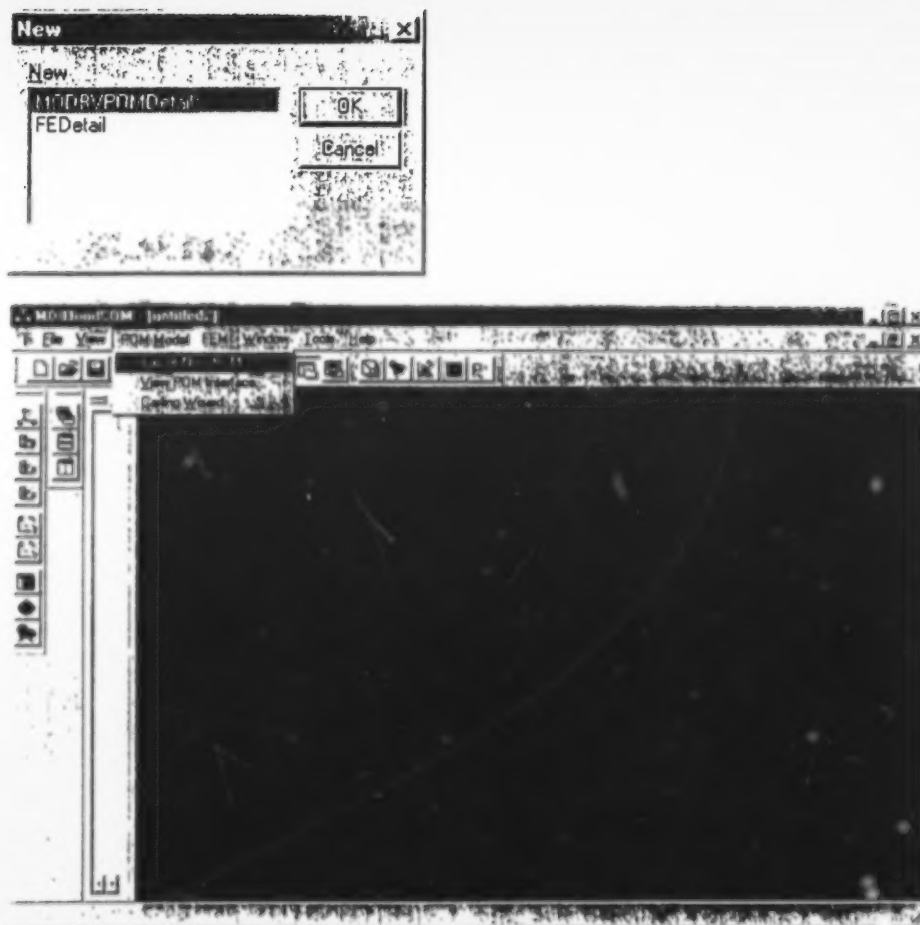


Figure 32: Starting a POM Hopper Model from Scratch

A default set of Hopper POM parameters are invoked to produce a 'default' hopper. The user then initiates the **Create New POM** option from the **POM Model** menu to modify the default data to create his own hopper, as shown in Figure 33.

The model creation process then follows the same as described above for modifying various parameters and meshing options.

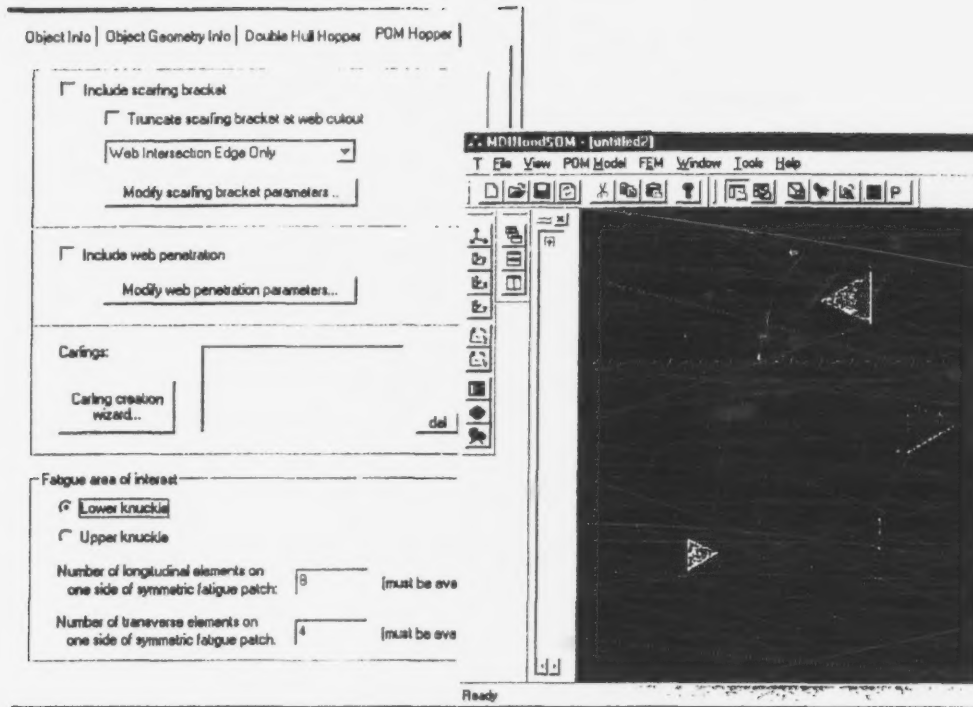


Figure 33: POM Property Page and Default POM Hopper Model to Create a New Model

4.5 Hopper POM Operations in Brief

The following gives a brief outline of the steps in producing a hopper detail model, beginning and ending with DSA.

1. Start DSA and open the global MAESTRO model and result files in MAESTRO (MG) mode.
2. Set the MDIHOODSOM path in the DSA Resources-Configuration GUI.
3. Switch to DSA mode (lower right) and isolate the hopper area of interest with Erase/Restore and zoom features.
4. Invoke the Structural Details menu through the Application Interface menu in DSA to define data for the HOOD Hopper POM.

5. Identify hopper location and orientation in DSA with the Control Points data entry menu.
6. Create HOOD Parameter Object Model (POM) data file from DSA. POM data is initially taken from MAESTRO model data.
7. Launch HOOD Hopper POM Application with POM data file from DSA.
8. Modify POM data such as web cutouts, brackets, stiffeners, thicknesses with the menus provided in the Hopper POM Application, POM Model menu.
9. Create FE mesh with FEM menu in the Hopper POM Application.
10. View the POM or FEM via standard HOOD view features
 - ☐ holding left mouse button down rotates models,
 - ☐ holding right mouse button down zooms model in and out of screen,
 - ☐ holding shift key and using left mouse button translates (pans) model on screen.
11. Edit the mesh through Mesh Options under the Tools menu in the Hopper POM application, if desired.
12. Export the FE mesh to DSA with Export FE Detail to MGDSA under the FEM menu item in the Hopper POM application.
13. In DSA import the DSA database created by the HOOD Hopper POM application with the Import from HOOD item in the Structural Details menu which is invoked from the Application Interfaces option in the Resources menu.
14. Automatically generate master and slave nodes and assign parent elements for top-down analysis with the Master and Slave Nodes and Parent Element Assignment options of the Structural Details menu.
15. Continue with top-down FEA fatigue analysis in DSA – see DSA manual.

5. Conclusions

This technical memorandum has described a new approach to rapidly producing finite element models for ship structural analysis. The approach is entitled Smart Rapid Structural Analysis (SRSA) as it encompasses aspects of expert systems in developing models for specific structural analysis and does so very quickly. The SRSA method allows engineers who are not expert in particular finite element programs, to rapidly produce good models for analysis, thus making finite element analysis much more available to them to improve design efficiencies and safety.

The DREA Hierarchical Object-Oriented Developers Tool Kit (HOOD TK) programming environment has been used to produce the Hopper POM application via Smart Object Models (SOMs) which encompass the data and methods of ship structural objects necessary to build geometric and finite element models of themselves. The HOOD TK environment has proven to be very versatile and effective in producing superior ship structural analysis applications with common user friendly interfaces and has allowed code re-use by a team of programmers.

The SRSA method as applied to a commercial bulk carrier hopper structure has been illustrated in this TM. The Hopper POM product has been very successful and has allowed users to produce hopper finite element models in a couple of hours (or less) rather than the several weeks required previously with conventional general purpose finite element modellers. The HOOD Hopper POM application has been successfully integrated with the DSA-MAESTRO ship analysis system which has many users throughout the world.

6. Acknowledgements

The DREA and Martec Ltd developers of the HOOD TK system and the DSA code, would like to thank Bureau Veritas, Lloyds Register of Shipping, The Royal Netherlands Navy, the U.K. Ministry of Defence and the MARIN Cooperative Research Ships organizations who have all contributed funding and valuable expertise to these products.

7. References

1. MAESTRO - Method for Analysis Evaluation and Structural Optimization, User's Manual - Version 7.1.1', distributed by Proteus Engineering, Stevensville, Maryland, USA, January 1996.
2. Pegg N.G. Norwood M.E., 'A Program Suite for Analysis of Ship Structure: DSA - Detail Stress Analysis', DREA Technical Memorandum in production, 2001
3. Stredulinsky D.C., Heath D.C., 'VShip Visualizer User's Guide', DREA Technical Memorandum 2000-140, 2000.
4. Smith M.J., Pegg N.G., 'Automated Assessment of Ultimate Longitudinal Strength of Ship Hulls', DREA Technical Memorandum 2000-143, November 2000,
5. N.G. Pegg, D.C. Heath, T. McAdam, 'Submarine Structural Analysis Suite (SubSAS)', Canadian Marine Hydrodynamics and Structures Conference, Vancouver, May, 2001.

UNCLASSIFIED

DOCUMENT CONTROL DATA		
(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)		
1. ORIGINATOR (the name and address of the organization preparing the document. Organizations for whom the document was prepared, e.g. Establishment sponsoring a contractor's report, or tasking agency, are entered in section 8.)	2. SECURITY CLASSIFICATION (overall security classification of the document including special warning terms if applicable).	
DREA	UNCLASSIFIED	
3. TITLE (the complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S,C,R or U) in parentheses after the title).		
Smart Rapid Structural Analysis (SRSA) for a Bulk Carrier Hopper Structure		
4. AUTHORS (Last name, first name, middle initial. If military, show rank, e.g. Doe, Maj. John E.)		
David Heath, Neil Pegg (DREA) Tom McAdam, Merv Norwood (Martec Ltd)		
5. DATE OF PUBLICATION (month and year of publication of document)	6a. NO OF PAGES (total containing information include Annexes, Appendices, etc).	6b. NO OF REFS (total cited in document)
October 2001	47	5
7. DESCRIPTIVE NOTES (the category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered)		
DREA TM		
8. SPONSORING ACTIVITY (the name of the department project office or laboratory sponsoring the research and development. Include address)		
Defence Research Establishment Atlantic PO Box 1012 Dartmouth, NS, Canada B2Y 3Z7		
9a. PROJECT OR GRANT NO. (if appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant).	9b. CONTRACT NO. (if appropriate, the applicable number under which the document was written)	
Project 1.g.c.11		
10a. ORIGINATOR'S DOCUMENT NUMBER (the official document number by which the document is identified by the originating activity. This number must be unique to this document.)	10b. OTHER DOCUMENT NOs. (Any other numbers which may be assigned this document either by the originator or by the sponsor)	
	DREA TM - 2000 - 170	
11. DOCUMENT AVAILABILITY (any limitations on further dissemination of the document, other than those imposed by security classification)		
☒ Unlimited distribution ☐ Defence departments and defence contractors; further distribution only as approved ☐ Defence departments and Canadian defence contractors; further distribution only as approved ☐ Government departments and agencies; further distribution only as approved ☐ Defence departments; further distribution only as approved ☐ Other (please specify):		
12. DOCUMENT ANNOUNCEMENT (any limitation to the bibliographic announcement of this document. This will normally correspond to the Document Availability (11). However, where further distribution (beyond the audience specified in (11) is possible, a wider announcement audience may be selected)		

UNCLASSIFIED

13. **ABSTRACT** (a brief and factual summary of the document. It may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall begin with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (S), (C), (R), or (U). It is not necessary to include here abstracts in both official languages unless the text is bilingual).

This technical memorandum describes the development of a new approach to increasing the efficiency of structural modelling and analysis and its application to commercial hopper structures of bulk carriers. This approach is entitled SRSA (Smart Rapid Structural Analysis) which makes use of DREA's object-oriented programming system, HOOD TK (Hierarchical Object Oriented Developers Tool Kit) which has been developed over the past several years to improve the development of software applications for naval ship structures. The HOOD TK is used for the development of 'Smart Object Models' (SOMs) which are programming entities that fully describe the geometry and analysis parameters of a structural component (ie. decks, bulkheads) and its relationship to other components. The SOMs are used to describe all of the basic ship structural components which are assembled, as required, into larger structural component applications through a 'Parametric Object Model' (POM). The bulk carrier hopper described in this report is a POM application. This TM describes the base Hopper POM development which has been used to produce specialized POMs for classification societies who are using it for fatigue analysis. The Hopper POM application is executed from the code DSA (Detail Stress Analysis) which extracts data from a global MAESTRO finite element model of a bulk carrier to populate the POM database and then receives the detail finite element model created from the Hopper POM application for use in fatigue analysis. The Hopper POM application has reduced finite element mesh production from several weeks to a couple of hours or less.

14. **KEYWORDS, DESCRIPTORS or IDENTIFIERS** (technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included if possible keywords should be selected from a published thesaurus. e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus-identified. If it not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title)

Ship structures
Finite element analysis
Meshing
Fatigue
Object-oriented programming

UNCLASSIFIED

A mod. 17 Dec 1997